LAKE OKEECHOBEE
PILOT DREDGING PROJECT REPORT

Prepared For:

South Florida Water Management District
3301 Gun Club Road
West Palm Beach, FL 33406

Prepared by:

EA Engineering, Science, and Technology, Inc.
15500 New Barn Road, Suite 200
Miami Lakes, FL 33014
(305) 819-2212

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ACRONYMS & ABBREVIATIONS

%	percent
µg/L	Micrograms per liter
ASR	Aquifer Storage and Recovery
ASTM	American Society for Testing and Materials
Bgs	Below ground surface
CDF	Confined Disposal Facility
CERP	Comprehensive Everglades Restoration Plan
Cm	centimeter(s)
COE	United States Army Corps of Engineers
CompQAP	Comprehensive Quality Assurance Plan
CY	Cycles
DGPS	Differential Global Positioning System
District	South Florida Water Management District (see also SFWMD)
DQO	Data Quality Objective
EA	EA Engineering, Science, and Technology, Inc.
EPA	(United States) Environmental Protection Agency
ER-L	Effects Range-Low
ER-M	Effects Range-Medium
ERP	Environmental Resource Permit
FDEP	Florida Department of Environmental Protection
Fe	Iron
$FeCl_3$	ferric chloride
Fe_{tot}	Total Iron
Ft	foot, feet
G	gram(s)
G/cm^3	Grams per cubic centimeter
Gal	gallon(s)
Gpm	Gallons per minute
GPS	Global Positioning System
HDPE	High-density Polyethylene
IFAS	Institute of Food and Agricultural Sciences
IL	Intercounty Laboratories
KHz	Kilohertz
Kts	Knots
Mg/L	Milligram per liter

ACRONYMS & ABBREVIATIONS (continued)

MGD	Million Gallons per Day
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MSL	Mean Sea Level
NGVD	National Geodetic Vertical Datum
O&M	Operation and Maintenance
Ortho P	Ortho Phosphorus
P	Phosphorus
PDS	Pilot Dredging Site
PEC	Probable Effect Concentrations
PEL	Probable Effect Levels
ppb	parts per billion
PPL	Priority Pollutant List
Psi	pounds per square inch
PWTS	Pilot-scale Water Treatment System, Pilot Water Treatment System
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
RESI	Rockett Environmental Services Inc.
SFWMD	South Florida Water Management District ("District")
TCLP	Toxicity Characteristic Leaching Procedure
TDH	Total Dynamic Head
TEC	Threshold Effect Concentrations
TEL	Threshold Effect Levels
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
USCG	United States Coast Guard
WTP	Water Treatment Plant

EXECUTIVE SUMMARY

This report prepared by EA Engineering, Science, and Technology, Inc. (EA) of Miami Lakes, FL, describes activities undertaken during the implementation of the Lake Okeechobee Pilot Dredging Project sponsored by the South Florida Water Management District (District). It includes results and observations from pilot dredging conducted in Lake Okeechobee during May 2002 using an innovative dredge head based on EA's patented SEDCUT® Sediment Removal Technology. Conceptual approach and recommendations for conducting commercial scale dredging in larger areas of the lake are also included.

The primary objective of the pilot dredging project was to demonstrate effectiveness of an innovative sediment dredging technology in removing the phosphorus laden mud sediment layer from the bottom of Lake Okeechobee, and doing so with a minimal contribution to turbidity in the in-lake water column. The SEDCUT® technology was specially developed to achieve this goal and field testing was conducted in Lake Okeechobee to determine efficacy of the specially manufactured innovative dredge head.

Results indicate that SEDCUT® technology was very successful in achieving the goals of the project. Using a 6 in [15 cm] mouth opening and travel rate of 40 fpm [12 m/min], the SEDCUT® dredge head successfully removed a dredge slurry containing 65% target mud and 35% dilution water.

Review of the turbidity data did not indicate any significant increase in water column suspended solid levels that could be directly attributed to the operation of the dredge head. The lake waters are characterized by naturally high turbidity levels and no distinct turbidity plume was observed during the field demonstration. Results of in-lake water quality monitoring indicated no significant difference in water quality between samples collected upstream and downstream of the dredging area, as compared to the samples collected within the active dredging zone. This shows that the operation of the SEDCUT® unit did not adversely impact in-lake water quality.

In short, the SEDCUT® technology is suitable for conducting dredging under conditions typical of the Lake Okeechobee sediment bed for the following proven reasons:

1. It successfully and efficiently removes the targeted mud layer with minimal resuspension of solids.

2. It minimizes the amount of dilution water that is produced during dredging thereby reducing treatment and handling costs.
3. It can be used in shallow waters.
4. It can be scaled up for use in the larger areas of the lake where the sediments are known to be concentrated.
5. Even though the approach is innovative, the technology is very cost-effective since the dredge head is assembled using mostly off-the-shelf products.

E.1 PROJECT BACKGROUND

Lake Okeechobee is a large multi-function lake/reservoir located at the center of both the Kissimmee-Okeechobee-Everglades aquatic ecosystem and the Central and Southern Florida Project. This Lake provides regional flood protection, water supply for agricultural, urban, and natural areas as well as critical habitat for fish and wildlife in south Florida. However, the environmental health of this critical water body has deteriorated over the past century, largely because of increased nutrient inputs.

In 1999, the Lake Okeechobee Issue Team of the District developed an action plan for the restoration of Lake Okeechobee. This Plan recommended the removal of all or part of the nutrient laden fluid mud sediments (i.e. upper layers of the lakebed sediment column) to the maximum extent practicable, in order to substantially reduce ecosystem internal phosphorus loading. If these sediments are removed, they must be processed and disposed of in a manner that will not recontribute phosphorus to the lake or other regional water resources. These sediments in Lake Okeechobee cover more than 80,000 hectares of the lakebed; the approximate volume has been estimated at 200 million cubic meters[1]. This amount of material is of an order of magnitude greater than has ever been removed from any lake in the world[1].

The large area of the lake and the fluid character of the upper sediment layer highlight the limitations associated with traditional hydraulic and mechanical dredging techniques. Currently used hydraulic dredge methods remove large volumes of water and may results in removal of non-target material. Excess material removal and treatment could raise the cost of the project's materials to prohibitive levels. Additionally, conventional means—typically designed for larger grain sizes—would tend to resuspend the fine material back into the water column. Finally, it is

[1]As mentioned in the District Lake Okeechobee Pilot Dredging Project RFP C-11651.

necessary that the selected technique for dredging should not add significantly to the already high levels of suspended solids and turbidity in the lake water.

An innovative sediment removal technology was therefore deemed necessary to remove all or part of the fluid mud sediment layer in Lake Okeechobee in order to substantially reduce internal phosphorus loadings. In response to the District's need, EA designed, manufactured, and demonstrated the effectiveness of the SEDCUT® dredge head in selectively removing targeted mud layer. This technology is uniquely suited for conducting dredging in Lake Okeechobee because:

1. It allows selective removal of the phosphorus-laden mud layer with minimal resuspension of this material into the water column.
2. It significantly reduces the amount of dilution water that is produced during dredging, thereby reducing treatment and handling costs.
3. It can be easily scaled up for use in the larger areas of the lake where the sediments are known to be concentrated.

In addition to performing pilot dredging in Lake Okeechobee using the new SEDCUT® technology, the project work plan also included the following:

1. **Selecting a representative Pilot Dredging Site (PDS) and identifying a location for siting a Confined Disposal Facility (CDF)** – A representative PDS was identified at a location approximately 5 miles southwest of the Port Mayaca Lock on the eastern side of the lake. A District-owned parcel of land, located along the northern bank of St. Lucie Canal, approximately ¼ mile east of Port Mayaca Lock was selected for constructing the CDF. The CDF would be used to temporarily store the sediments dredged from the lake.

2. **Obtaining relevant regulatory permits** – A joint Environmental Resource Permit was obtained from the Florida Department of Environmental Protection (FDEP), which permitted conducting dredging in the Lake and designing, constructing, and operating a CDF to hold the dredge sediments. The FDEP permit also allowed for the design, construction and operation of a pilot water treatment system (PWTS) to treat the water that separates from the stored dredged material and return it to the CDF. A dredging permit was also obtained from the Army Corps of Engineers. The CDF was constructed under a separate construction permit from Martin County.

3. **Characterizing site-specific sediments** – Sediment core samples were obtained from the PDS and subjected to physical and chemical characterization. Results showed that the target mud layer at the PDS was characterized by average bulk density of 1.20 g/cm^3, mean solids content of 21 percent by weight, with an average of 37 percent of those solids organic in nature. No pesticides were detected in the sediment samples. Concentrations of arsenic, cadmium, and mercury detected in the site-specific sediments slightly exceeded screening values, however they were determined not to be at levels of concern as the concentrations fell into the "medium-low priority" ranking.

   In addition, sediment concentrations were also compared to soil cleanup target levels (FAC 62-777). Results indicated that except for arsenic, concentrations of all other constituents were below the available soil cleanup target level.

4. **Conducting water quality monitoring** – Water quality monitoring was conducted in parallel with the field demonstration to determine impacts on in-lake water quality resulting from operation of the SEDCUT® dredge head, and to evaluate efficacy of the selected water treatment technology in reducing total phosphorus concentrations in the CDF effluent. Water quality monitoring also included monitoring of in-lake water column turbidity levels before, during, and after dredging.

   Review of the in-lake water quality monitoring data indicated no significant difference in water quality (selected nutrients and metals) between samples collected upstream and downstream of the dredging area, as compared to the samples collected within the active dredging zone. Concentration of metals recorded in the water column were compared to FDEP's water quality criteria for Class I surface water body. The comparison indicated that except for one iron value (out of four measurements), which slightly exceeded the criteria (measurement of 3,230 μg/L compared to criteria of 3,000 μg/L), all other metal concentrations were below the water quality criteria for Class I water bodies.

   Turbidity monitoring data also indicated no significant impact on lake turbidity levels during dredging. Turbidity values recorded before, during, and after dredging was completed did not differ from each other significantly. The background lake turbidity levels were relatively high and the operation of the SEDCUT® unit was shown to have little impact on the turbidity levels. None of the QA/QC samples indicated problems with sample collection, handling, or analyses.

5. **Conducting Bathymetric Surveys** – Bathymetric data was collected before, during, immediately after, and approximately ten days after pilot dredging was completed. Surveys were conducted using the **Reson 8124 SeaBat** multi-beam depth sounder and a **Knudsen 320M** dual-frequency depth sounder. Use of dual-frequency and multi-beam technology allowed for a more detailed determination of the top surface of the mud layer. Comparison of data collected before dredging began (pre-dredging survey), during dredging (progress survey), and after dredging (post-dredging survey) was used to determine changes in bathymetry associated with the dredging. Data collected several days after completion of the dredging (follow-up survey) was compared to the post-dredging survey data to determine if and how rapidly the dredged area refilled with fluid muds from the surrounding area.

   Multi-Beam Surveys were conducted with a 25'-30' [8-9 m] line spacing to determine the fluid mud layer. This line spacing allowed an overlap of 15 ft [5 m] with each adjacent survey line and provided 100% coverage of the surveyed area. Dual frequency surveys were conducted with a line spacing (transects) of 50' [15 m], covering a bottom width of 1–2 ft [30–60 cm] over the length of the survey line with no overlap of covered areas.

   The results of the surveys indicated that measuring a small vertical face in sediments that are very soft and non-homogeneous is difficult to quantify, especially in a shallow, open lake subject to rapid and heavy weather changes such as Lake Okeechobee. While the multi-beam survey provided sufficient data to eliminate any interpolation of data that is inherent in other surveys that traditionally utilize parallel survey lines, this approach is extremely expensive to conduct over very large areas. In addition, given the accuracy of the vertical measurement of 1 tenth to 2 tenths of a foot, the error introduced in measuring 1.2 ft (30 cm) of material is very significant (approximately 8-16 %). This degree of accuracy in achieving depths is normally of much less concern in projects removing larger face heights of material since it represents a much smaller percentage of the total.

   Review of the post-dredging survey output indicated that some relatively heavy shoaling had occurred since dredging was completed. This shoaling was small in height but was expansive in area. It could not be concluded with any certainty as to the constant nature of the magnitude of the shoaling. In the course of execution of any larger lake project, consideration must be given to the constant shifting of the soft sediments that is likely to occur during the course of dredging. In other words, areas dredged may not be 100 % cleaned of any soft sediment since some lateral transport of material is likely to take place, especially over longer periods of dredging activity.

6. **Designing, constructing, and operating a CDF** – The purpose of the CDF was to provide an environmentally isolated, temporary storage area for sediments after they were dredged from the lake bottom. After being deposited into the CDF, the dredged material was allowed to settle for 24-48 hours. Upon settling, a portion of the liquid fraction was skimmed from the top of the CDF and fed into the PWTS for treatment to remove phosphorus. The CDF was designed in accordance with the guidelines for minor impoundments established by the District. Upon completion of the project, the CDF will be handed over to the District for periodic inspection, as-needed maintenance (of security fence, erosion control measures, etc.), and eventual closure.

7. **Designing, constructing, and operating a PWTS** – The primary objective of the pilot water treatment process was to evaluate the effectiveness of alternative water treatment technologies for the removal of total phosphorus (TP) from the supernatant of Lake Okeechobee dredge sediments. The target TP concentration of the supernatant after treatment was less than or equal to 40 µg/L. Two technologies were demonstrated during the project: chemical precipitation using ferric chloride followed by flocculation with a high-molecular-weight polyacrylamide-based polymer (NALCLEAR 8184, Nalco Chemical Co.); and chemical precipitation using ferric chloride followed by microencapsulation with a silica based a microencapsulating agent (KB-1, KEECO Inc.). Supernatant treated during PWTS processing had influent TP concentrations ranging from 97 to 177 µg/L.

   Results from the chemical precipitation/flocculation process field tests indicated that five out of seven process trials met the project target goal of reducing phosphorous concentrations to 40 µg/L or less. The chemical precipitation/microencapsulation process was even more successful; all seven process trials achieved the project target goal of 40 µg/L.

8. Water quality monitoring for determining lake readiness of the effluent from the pilot water treatment system indicated the PWTS effluent for both the polymer flocculation and microencapsulation technologies had iron concentrations that did not meet project screening

criterion. PWTS effluent for the chemical polymer flocculation technology also had pH levels that did not meet project screening criterion.

E.2 FIELD DEMONSTRATION OF THE SEDCUT® TECHNOLOGY

Prior to the field demonstration, EA designed, manufactured, and tested a dredge head based on the SEDCUT® technology. Discrete lanes, approximately 200 ft [61 m] in length, were dredged using the SEDCUT® dredge head. Adjustments to the dredge mouth opening height, travel speed, and contact pressure were made for selected lanes. A pumping rate of approximately 1,300 gallons per minute [5,000 l/min] was used for all lanes. Sediments removed during each lane cut were pumped directly into one of the eight compartments of a tank barge for temporary storage prior to transfer to the CDF at the end of the day.

For each lane cut, grab samples of the dredge slurry were collected at the tank barge directly from the 6 in discharge line. These samples were analyzed in the field, to determine the approximate percentage of mud collected versus dilution water during each lane cut, and to provide feedback on the dredge's performance.

Aliquots of the slurry samples were also shipped to an analytical laboratory for determination of standard physical properties. The success of dredging (i.e. accurately removing the target mud layer) was determined by comparing the bulk density and grain size distribution properties of the dredge slurry to the known properties of the target material. The efficiency and production rates of the dredging operations were determined by the relative volume ratio of mud versus dilution water in the dredge slurry.

Results from the survey data were able to confirm that a thin layer of mud (approximately 30 to 45 cm) was removed from the dredge lanes. The survey data was also able to confirm that the dredge lanes were being filled in with the surrounding muds; the rate of filling, however, could not be determined.

Four mouth openings (6, 8, 10, and 12 in) were tested in the field at differing travel rates at an approximate pumping rate of 1,300 gpm [5,000 l/min]. Two and four in mouth openings were also tested during the shake down period. Results indicated that dredging with a 6 in [15 cm] opening at a travel rate of 40 ft/min [12 m/min] was able to generate a dredge slurry with a volume ratio of 65% target mud and 35% dilution water (Table E-1).

Table E-1 Summary of Actual Mud Production Rates for the 6 in mouth opening

% Volume of mud in dredge slurry		Travel Rate	Travel Rate
Low	**High**	**(fpm)**	**(m/min)**
56	65	40	12.0
35	61	33	10.2
51	60	28	8.4
41	54	20	6.0
17	24	15	4.8
32	39	11	3.6
12	25	5.5	1.8

The contact pressure was also adjusted by flooding the ballast tanks. The ballast tanks were flooded on the last lane cut to add more weight to the dredge head. The additional weight was shown to lower dredge depth by 0.9 ft [27 cm].

The relative volume ratio of 65% target mud and 35% dilution water observed during the pilot test is believed to represent acceptable production rates and that this rate can be increased with further optimization of the unit. To the best of our knowledge, no large-scale commercial dredging has ever been conducted in Lake Okeechobee therefore SEDCUT® production rates cannot be compared to other more conventional technologies.

E.3 SCALABILITY

The SEDCUT® technology is based on three inherently scalable fundamental principals, namely:

1. A intake visor (i.e. mouth opening height) that limits the amount of dilution water entrained during dredging;
2. Buoyancy tanks that can control substrate contact pressure, so the dredge head can slide on a selected substrate density plane; and
3. Mud gathering rates equal to or slightly greater than dredge pumping rate.

All three of these design principles were tested during the pilot project and were shown to be effective. It must be noted that even though the technology is innovative, the unit is constructed from easily available, off-the-shelf components.

A conceptual approach was developed for conducting large-scale commercial dredging in Lake Okeechobee. This approach is based of the results from the pilot-scale field demonstrations and is aimed at removing up to 200 million cubic yards[2] [153 million cubic meters] of fluid muds from the lake over a thirty-year period (to coincide with other Lake Okeechobee Watershed restoration efforts being implemented under the Comprehensive Everglades Restoration Plan [CERP]). A linear extrapolation approach was used since the dredge head used during the pilot study was constructed to scale (6 ft [2 m] wide with one, 6 in [15 cm] pump) and the full-scale unit is projected to be four times the size of the pilot, i.e. 24 ft [7 m] wide with four, 6 in [15 cm] pumps. Therefore, the time required to remove 200 million cubic yards [153 million m^3] can be reduced or increased in a linear manner by varying the number of full-scale units.

Daily and yearly dredging production rates were forecasted based on the following assumptions:

1. 200 million cubic yards [153 million m^3] of fluid muds from the lake over a thirty-year period.
2. The SEDCUT® dredging technology will produce dredge slurry containing 65% target mud and 35% dilution water.
3. Dredge operations are assumed to operate on an 24 hours/day 7 days/week with approximately 15% downtime for weather, holidays, etc.
4. Dredge slurry can be transported to constructed island or other engineered containment structures for disposal and/or management.
5. Dilution water from the dredge slurry will separate from the dredge material within 24 hours. This water will have to be treated to reduce total phosphorus concentrations to below 40 ug/L prior to returning it to the lake. Alternative uses for the dredge slurry supernatant may include use as irrigation water.

Volumes associated with the above assumptions are shown in Table 9-1.

Increasing the production rate of the pilot dredge unit can be accomplished by increasing the width of the SEDCUT® sliding dredge head and adding more hydraulic pumps. The full-scale dredge unit needed to pump 4,270 gpm [16,000 l/min] of dredge slurry would be four times larger than the pilot unit (24 ft [7 m] wide with four, 6 in pumps equally spaced along the SEDCUT® dredge head). The variation of pump sizes and configurations can easily be tailored to

[2] The total amount of fluid muds estimated to be present in Lake Okeechobee (District RFP C-11651).

maximize efficiency for scalability purposes; assuming a consistent sediment layer thickness, the pilot dredge unit can be linearly expanded to the desired capacity merely by adding width and pumping capacity.

A major element of the cost of such dredging operations will involve the transport, management, and disposal of the dredged material. For this aspect of the operation, there are many standard dredging techniques offering large economies of scale and reduced susceptibility to wind and water surface conditions. A series of fixed pipelines—each serving different segments of the Lake over the several years of the dredging operation—could offer much simpler and lower-cost transport and transfer operations, and much less weather and water-depth vulnerability than were encountered during the pilot study. Navigation impacts can be minimized by submerging the entire pipeline or portions that cross the navigation channels.

In addition, it is known that the mud layer is thickest at the center of the lake and is of negligible thickness as much as 2 miles [3 km] from the shore. This not only significantly reduces the area required for dredging, but also offers alternative dredging options. For example, it may be possible to only dredge the central 10 miles [16 km] diameter of the Lake, and exploit the natural forces that concentrate the mud in the center of the Lake over time to efficiently remove the majority of this material in a multi-year program.

Both water treatment technologies demonstrated during the pilot project were successful in reducing total phosphorus concentrations in the dredge effluent to below 40 µg/L. Both technologies used standard chemical precipitation followed by solids separation (polymer/ encapsulation using KB-1). Scale up of either of these systems would be in accordance with conventional water treatment plants and similar to the chemical treatment systems proposed for the District's storm water treatment areas[3]. However, additional studies are needed to demonstrate the optimization from scaling up from a 10 gpm [38 l/min] to a 2–4 million gallons/day (MGD) [7.5–15 million l/day] plant and to better optimize the cost effectiveness of treating and discharging large amounts of water back to the lake.

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[3] "Chemical Treatment Followed by Solids Separation Advanced Technology Demonstration Project." Final Report prepared by HAS Engineers & Scientists for the South Florida Water Management District (Contract # E10650). Dec 2000.

E.3 RECOMMENDATIONS

The SEDCUT® technology showed strong promise as an effective option to accomplish the objectives of the Comprehensive Lake Restoration Plan. However, additional data is needed to accurately forecast of the cost and time required for a full-scale dredging operation of the entire Lake. While the pilot test indicated that the SEDCUT unit could penetrate a deeper sediment layer (as shown by dredging conducted with flooded ballast tanks), additional testing is proposed.

Specifically there is a need to determine the removal efficiency of dredging different sediment layers at various depths and locations. This can be accomplished by conducting pilot dredging operations in the center of the Lake where mud layers have been determined to be the thickest (greater than 4 ft [1.2 m]) and around the perimeter of the Lake where mud layers are between less than 4 [1.2 m] ft thick.

1.0 INTRODUCTION

This Lake Okeechobee Pilot Dredging Project Report has been prepared by EA Engineering, Science, and Technology, Inc. (EA) of Miami Lakes, FL, for the South Florida Water Management District (District), under contract number C-11651. The report describes the activities undertaken during the course of the project and presents results and observations from pilot dredging conducted in Lake Okeechobee.

1.1 PROJECT BACKGROUND

Lake Okeechobee is a large multi-function lake located at the center of both the Kissimmee-Okeechobee-Everglades ecosystem and the Central and Southern Florida Project. The lake provides regional flood protection, water supply for agricultural, urban, and natural areas as well as critical habitat for fish and wildlife in south Florida. However, the environmental health of this critical water body has deteriorated over the past century, largely because of increased nutrient inputs.

In 1999, a multi-agency Lake Okeechobee Issues Task Force developed an action plan for the restoration of Lake Okeechobee. This Plan recommend removal of all or part of the nutrient laden fluid mud sediments (i.e. upper layers of the lakebed sediment column) to the maximum extent practicable, in order to substantially reduce ecosystem internal phosphorus loading. If these sediments are removed, they must be processed and disposed of in a manner that will not recontribute phosphorus to the lake or other regional water resources. These sediments in Lake Okeechobee cover more than 80,000 hectares of the lakebed; approximate volume has been estimated at 200 million cubic meters (m^3). As mentioned in the District's request for proposal for this project, this amount of material is of an order of magnitude greater than has ever been removed from any lake in the world.

The large area of the lake and the fluid character of the upper sediment layer, together with the likelihood that excess quantities of either, in-lake water or substrate sands might be removed in a conventional hydraulic dredging process, create an enormous scale for material removal. Excess material removal and treatment could raise the cost of the project's materials to prohibitive levels. It was therefore necessary that the technique selected for dredging sediments in Lake Okeechobee should not add significantly to the already high levels of suspended solids and turbidity in the lake water. An innovative technology was therefore required to selectively remove only the target mud layer, and to do so with a minimum contribution to turbidity and the resuspension of solids.

1.2 PROJECT GOALS AND OBJECTIVES

The primary objective of the pilot dredging project was to demonstrate the feasibility and cost effectiveness of removing and processing the phosphorus laden mud layer using innovative dredging, material processing, and water treatment technologies. To accomplish this objective, the SEDCUT® technology was specially developed and tested during this project. As agreed upon in the contract, research and development costs for the new technology were borne by EA Engineering, which is in the process of finalizing a patent. The SEDCUT® dredge head was rented to the District for the duration of the field demonstration.

The SEDCUT® technology uses a specially designed dredge head (Figure 1-1) to selectively remove sediment layers and it was selected as a viable option for conducting dredging in Lake Okeechobee because:

1. It allows selective removal of the phosphorus-laden mud layer with minimal resuspension of this material into the water column.
2. It significantly reduces the amount of excess water that is taken-up during dredging, thereby reducing treatment and handling costs.
3. It can be easily scaled up for use in the larger areas of the lake where the sediments are known to be concentrated.
4. It can be assembled cost effectively using mostly off-the-shelf products.

In addition to demonstrating the effectiveness of the SEDCUT® technology, the project design also included achieving the following secondary objectives:

1. Obtaining relevant regulatory permits,
2. Characterizing site-specific sediments from the pilot dredging site,
3. Conducting environmental monitoring (water quality and bathymetric surveys) in parallel with the pilot dredging demonstration,
4. Designing, constructing, and operating a Confined Disposal Facility (CDF) to temporarily store the sediments after they are dredged from the lake bottom, and

Figure 1-1 SEDCUT Dredge Head

Dredge head mounted on the dredge plant

Close-up of dredge head

5. Designing, constructing, and operating a pilot scale water treatment system (PWTS) to treat the water (dredged material effluent) that separates out from the sediments stored in the CDF.

1.3 PROJECT WORK PLAN

A detailed work plan was developed and implemented to accomplish the project objectives[1]. To ensure that the project objectives were accomplished in a timely, organized, and cost-effective manner, the project was broken down into discrete tasks, several of which were implemented in parallel. The work plan was reviewed and approved by the District prior to implementation.

1.4 PROJECT HEALTH & SAFETY

Prior to initiation of field work, a project-specific Health & Safety Plan (EA, 2001a) was developed. Following approval by the District, the plan was implemented throughout the project to ensure that all field activities were conducted in a safe manner. Health and safety practices implemented at the site included regular safety meetings, training in proper use of field gear and equipment, periodic safety inspections, implementation of safe boating practices, etc.

1.5 PROJECT REPORT ORGANIZATION

This Project Report is organized into nine (9) chapters. Chapter 1 contained an introduction and included a discussion of the project objectives and scope. Selection of a representative pilot dredging site (PDS), and a suitable location to site the CDF and a shore transfer platform is described in Chapter 2. Chapter 3 summarizes the significant steps in the regulatory permitting process. Characterization of sediment samples collected from the PDS is described in Chapter 4.

A description of the field demonstration of the SEDCUT® technology is provided in Chapter 5. Chapter 6 describes environmental monitoring conducted in parallel with the pilot dredging. Details of the design, construction, and operation of the CDF are contained in Chapter 7. Chapter 8 describes the design, construction, and operation of the pilot water treatment system. Significant observations and recommendations from this study are presented in Chapter 9. A series of appendices are included to present supporting data.

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[1] *The Lake Okeechobee Pilot Dredging Project, Final Work Plan* (EA, 2001a).

2.0 SITE SELECTION

The process of selecting a suitable site for conducting pilot dredging and locating the CDF and a shore transfer platform began with the identification of available land parcels, preferably owned by the District, near the eastern and northern shoreline of Lake Okeechobee. The strategy was to first select an appropriate location to site the CDF and then choose a representative pilot dredging site in the Lake relatively close to the CDF. The shore transfer site would, by default, have to be placed between the two, preferably contiguous to the CDF, to eliminate the use of long pipelines.

2.1 CDF SITE SELECTION

Alternate locations were evaluated for siting the CDF based on the following criteria:

- Availability of 2 ½ to 3 acres [1 to 1.2 hectares] at an upland location
- Minimum clearing and grubbing (i.e., light brush)
- On-site burning of clearing debris preferably allowed
- Dikes to be constructed from material excavated from bottom of CDF
- Water table 4 ft [1.2 m] or more below the surface
- Access road to site 20 ft [6.1 m] wide and less than 1000 ft [304.8 m] long from existing road system

Two potential sites were evaluated based on the above criteria. Site 1 was located at the intersection of Nubbin Slough and Taylor Creek. This location was eliminated from further consideration since there was no direct access for a transfer barge to reach the site from Lake Okeechobee. Access via Taylor Creek was not possible due to the gates at S-191 being locked most of the time. Further, even when gates were open, a barge carrying the dredged material would not be able to pass through the low underpass at one of the roads that cross over Taylor Creek. Alternate forms of transporting the dredged material to this site (such as trucking, use of a pipeline) were considered but were found to be exorbitantly expensive.

The second site was located along the northern edge of the St. Lucie Canal less than $^{2}/_{3}$ of a mile [1.07 km] east of Port Mayaca Lock. This location met the desired criteria and was selected as the CDF site. Most importantly, it could be accessed very easily from the Lake through the Port Mayaca Lock via the St. Lucie Canal (the Okeechobee Waterway). Other criteria that favored the selection of the Port Mayaca site included the following:

- It is located on District-owned lands (Figure 2-2).
- There is adequate acreage available to locate a CDF to hold approximately 6,000 cubic yards (yd^3) [4587 m^3] of dredged material.
- Water depth in the St. Lucie Canal alongside the southern edge of the property is adequate to set up a shore transfer station.
- A District pump house (S-153) is located just off the northeastern edge of the property. This would potentially allow for relatively easy access to electrical and phone connections for the staging area, as needed.
- The northern edge of the property was demarcated by a flood control levee, which could, with very little modification, be incorporated into the design of the CDF.
- The property was located in a rural setting with very little local pedestrian and vehicular traffic.

2.2 SELECTION OF THE PILOT DREDGING SITE (PDS)

The contract and work plan specified that the PDS would be located within 1 mile of the general proximity of the eastern side of the Lake, and have a fluid sediment layer approximately 3 ft [0.91m] in thickness. A nominal dredging area of 225 ft X 225 ft [68.58 X 68.58 m] was indicated, leading to an expected dredged volume of 151,875 cubic ft (ft^3) [4300.6 m^3], or 5625 yd^3 (later rounded to 6000 yd^3 [4587 m^3]).

A review of existing data indicated that the target mud layer in the near-shore areas along the Port Mayaca shoreline of Lake Okeechobee was relatively thin (<2.5 in [10 centimeters (cm)]); and that there was inadequate water depth in most shore areas to accommodate a loaded dredged material barge/tug unit. Site investigation conducted at nearby areas approximately one mile [1.6 kilometer (km)] offshore yielded none or minimal fluid mud sediment layers: the thicker fluid mud sediment layers are concentrated in the lake pelagic zone. No appropriate sites were thus available within the one mile [1.6 km] zone specified in the work plan in the general proximity of the Port Mayaca CDF site. Consequently the decision was made to decrease the target dredge layer thickness and expand the search beyond the one mile [1.6 km] offshore.

Three alternate offshore sites (> 1 mile [1.6 km] from the shoreline) were evaluated based on the following criteria:

- Presence of a ≥ 12 in [30 cm] thick target mud layer
- Minimum of 7 ft [2.1 m] of water depth available from the dredge site to the navigation channel
- Area generally free of debris and large obstructions
- Mud layer that is underlain by sand substrate

A location approximately five miles [8.37 km] offshore from the western approach to the Port Mayaca Lock, on a magnetic bearing of 249 degrees offshore, was selected as the PDS (latitude 26? 57' and longitude 80? 42.3'). Sediment thickness at this location was > 12 in [30 cm] with a top sediment elevation of 1.5 ft [0.46 m] MSL. There was a thin, irregular sand layer underlying the mud at this location. Published bathymetric data showed that adequate tug/barge float water (i.e., =10ft [3.05 m]) should exist from this location through the Port Mayaca channel when the lake is at an elevation of 12.5 ft [3.81 m] MSL. A sediment boring profile from this location is illustrated in Figure 2-1.

The original plan was based on removing a three-foot thickness of sediment over a 225 ft x 225 ft (68.58 m x 68.58 m) area, one mile [1.6 km] offshore. Site conditions indicated that the closest representative site was five miles [8 km] offshore and only had a sediment thickness of 12 in [30 cm], which required a larger dredge area to equate to the original volume identified in the RFP.

2.3 SELECTION OF THE SHORE TRANSFER STATION

Since the CDF was to be located along the northern edge of the St. Lucie Canal, and use of long transfer pipelines was economically infeasible for a small demonstration project, a shore transfer station was established along the southern edge of the CDF site. This location had adequate navigational clearance and draft for the barge unloading equipment, as well as the loaded material, as long as the water elevation in the St. Lucie canal remained at ±10.0 ft [3.08 m] MSL. Location of the PDS and CDF are shown in Figure 2-2. For additional details, refer to the "*Lake Okeechobee Pilot Dredging Project - Site Selection & Conceptual Design*" (EA, 2001b).

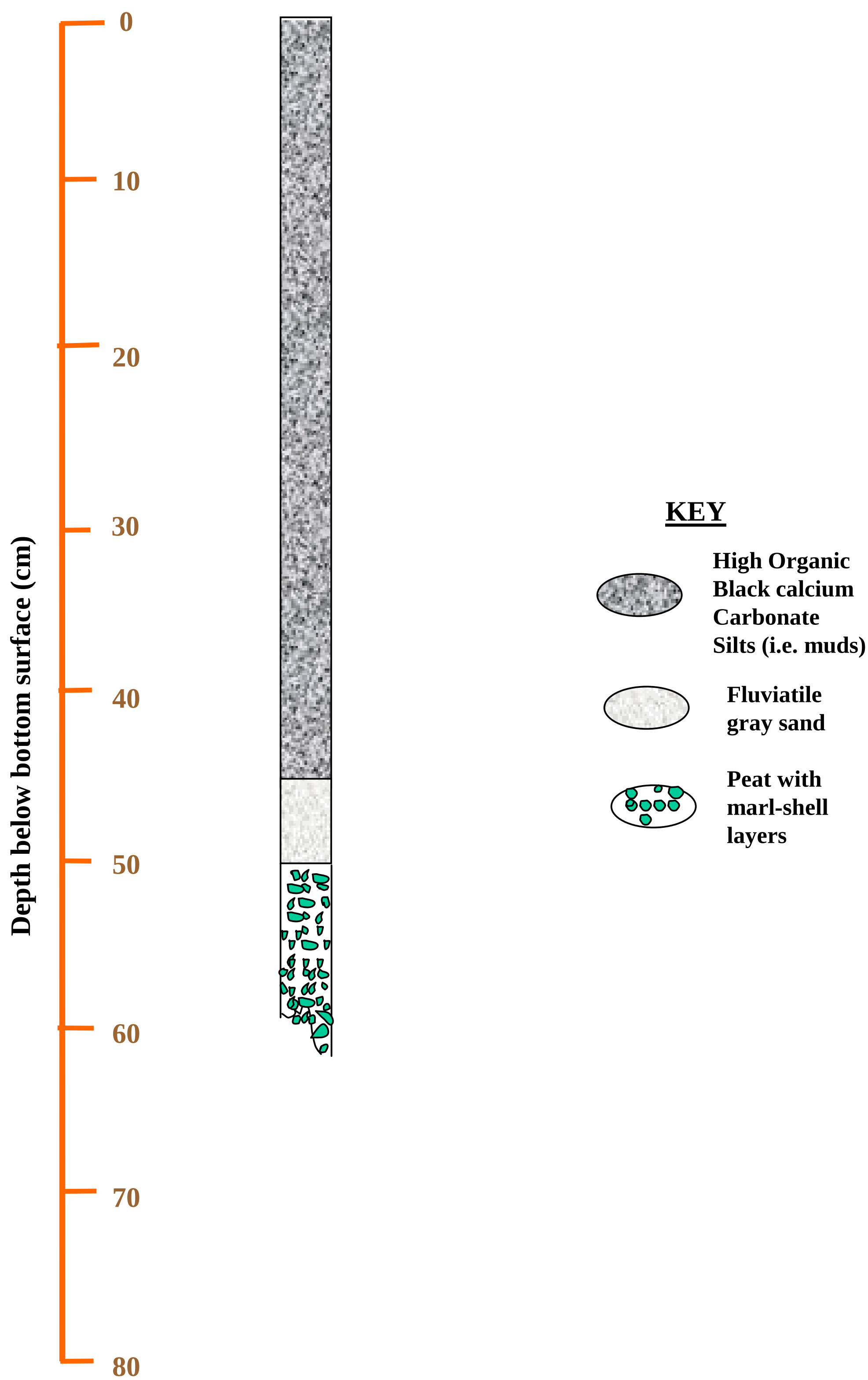
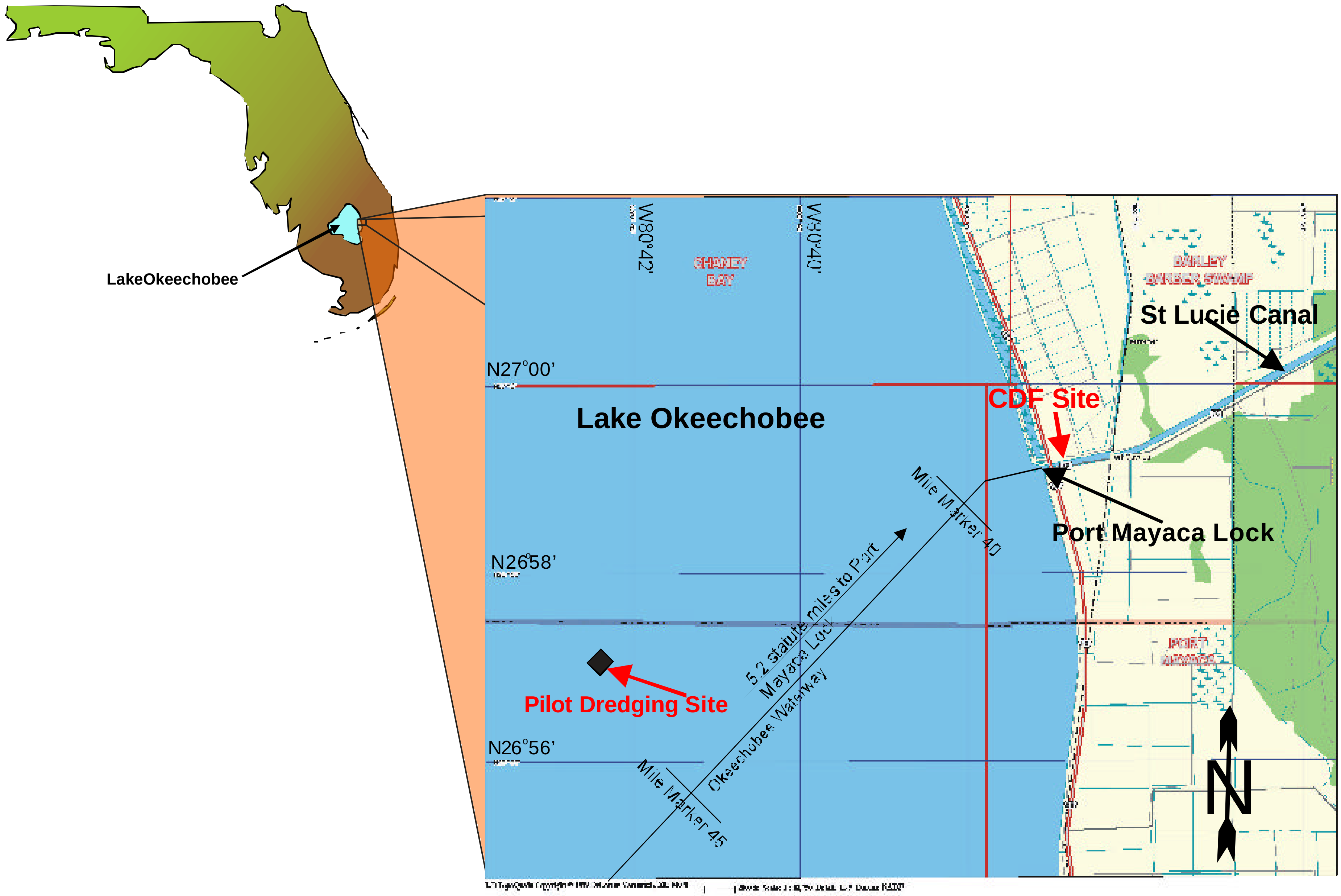


Figure 2-1 PDS Sediment Core Profile



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LAKE OKEECHOBEEPILOTDREDGINGPROJECT

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FIGURE2-2

3.0 PERMITTING

Florida State regulations require that prior to constructing a CDF and filling it with dredged materials, a permit must be obtained from the appropriate regulatory authority, including one or more of the following:

- The Florida Department of Environmental Protection (FDEP)
- The United States Army Corps of Engineers (COE)
- Water Management Districts

A joint application for an Environmental Resource Permit (ERP) is generally used to apply to all agencies concerned. EA submitted a completed joint ERP application for this project to the District in August 2001. Prior to submitting the permit application to FDEP, several meetings were held with representatives of various regulatory agencies to discuss relevant issues. Besides FDEP, representatives from the U.S. Environmental Protection Agency (EPA), the U.S. Fish & Wildlife, and the Fish & Wildlife Commission attended these meetings. Comments from all agencies were considered for inclusion in the permit application. Discussions were also held with the Coast Guard regarding navigation issues in the lake during periods of active dredging.

After signature by District personnel, the application was filed with the FDEP. Information submitted along with the permit application included a set of conceptual drawings illustrating the proposed CDF. FEDP issued permit number GL 50–0189610-001 on November 9, 2001 (Appendix A).

In response to the ERP application, the USACE issued permit number 200106177 (LP-DEB) on February 8, 2002. This permit allowed the dredging of 6,000 cubic yards [4587.3 m^3] of sediments from the PDS in Lake Okeechobee, and temporarily storing it in the project CDF (Appendix A).

Since the CDF was to be located in Martin County, Florida, a construction permit was also required from the Board of Engineering Department of the Martin County Board of County Commissioners. EA submitted an application on February 5, 2002, and a permit to construct and operate the CDF was received on March 4, 2002 (Appendix A).

A checklist of relevant and applicable permit requirements was developed and used during the project to ensure that all applicable conditions were complied with appropriately (Table 3-1).

It must be noted that all permits have been issued to the District. EA was responsible for ensuring that all relevant permit conditions were met during the project and that the District would be responsible for ensuring the compliance of relevant permit conditions after dredging operations were completed.

Table 3-1 Permit Requirement Checklist

Requirements	Due Date	Comments
A separate permit may be required by the USACOE. Authorizations may also be required by other federal, state, and local entities.	Obtain authorization prior to initiating construction.	Obtained permits from COE and Martin County. Also coordinating with the Coast Guard on navigation issues in the lake.
General Conditions		
1. All activities authorized by this permit shall be implemented as set forth the plans, specifications, and performance criteria as approved by this permit, Any deviation from the permitted activity and the conditions shall constitute a violation.	Duration of the Project.	Done.
2a A copy of this permit, with all conditions, attachments, and modifications is to be kept at the work site of permitted activity.	Duration of Project.	Copy provided to CDF Construction Contractor.
2b Give the permit to the contractor to review.	Prior to commencement of permitted activity.	Done.
3 Temporary erosion control is to be implemented prior to and during construction.	Permanent control measures is to be completed within 7 seven days of any construction activity.	Silt fences were installed at the CDF site prior to start of construction and were maintained throughout the duration of the project.
4a Notify FDEP of the anticipated construction start date.	Within 30 days of the permit issue date.	Was done as soon as a construction date was finalized.
4b Submit a "Environmental Resource Permit Construction Commencement" notice (Form No. 62-343.900(3), FAC) to FDEP indicating the actual start date and the expected completion date.	At least 48 hours prior to commencement of activity.	Done. A fax was sent out to DEP, COE, SFWMD, and Martin County on March 7 indicating that CDF construction was likely to start during the week of March 11.
5 If duration of construction will exceed one year, submit construction status reports to FDEP on an annual basis using an "Annual Status Report Form" (Form No. 62-343.900(4) FAC).	Due the following June of each year.	Not applicable.
6 Submit a written statement of completion and certification by a registered professional engineer or other appropriate individual as authorized by law, using the "Environmental Resource Permit As-Built Certification by a Registered Professional" (Form No. 62-343.900(5) FAC). If deviation from the approved drawings are discovered during the certification process, the certification must be accompanied by a copy of the approved permit drawings with deviations noted. Both the original and revised specifications must be clearly shown. The plans must be labeled "as-built" or "record" drawing. All surveyed dimensions and elevations must be certified by a registered surveyor.	Within 30 days after completion of construction of permitted activity.	Done.

Table 3-1 Continued

Requirements		Due Date	Comments
	The operation phase of the permit is not to become effective until requirements of condition 6 (above) have been met, a "Request for transfer Environmental Resource Permit Construction Phase to Operation Phase" (Form No. 62-343.900(7) FAC) has been submitted to FDEP, FDEP determines the system is in compliance with the permitted plans and specifications.		Done
9	May need to obtain any federal, state, local and special district authorization.	Prior to the start of any activity approved by the permit.	COE and Martin County approval were obtained prior to start of project.
13	FDEP should be notified if historical or archaeological artifacts are discovered at any time on the project site.	Notify the appropriate FDEP office immediately.	Not applicable.
14	Notify FDEP in writing if any previously submitted information that is later discovered to be inaccurate.	Notify FDEP immediately.	Not applicable
Special Conditions			
2a	*Instructions to Contractor.* Give a copy of this permit to each contractor and subcontractor.	Before authorized work begins.	Done.
2b	Schedule a pre-construction meeting for attendance by the contractor(s), owner or agent, and representatives from SFWMD, FDEP, and other environmental regulatory agencies to establish an understanding among the parties of the items specified in the special conditions of the permit.	Prior to construction.	Per conversation with Inger Hansen of DEP, this clause refers to in-water activities and not to construction of the CDF. A meeting was scheduled for April 5 to meet with and brief all regulatory agencies.
4	*Sediment Characterization.* Submit a Material Testing and Disposal Plan to the FDEP southeast district for review and approval. The dismantling of the CDF should begin until FDEP determines that the material has been adequately characterized and a final disposal option has been selected that is protective of human health and the environment and in compliance with applicable rules.	Prior to removing and disposing of the material from the CDF.	A sediment disposal plan will be submitted to FDEP following sediment characterization. Upon receiving approval, the sediments will be disposed off in accordance with the plan, the CDF will be dismantled, and the site will be restored.
5	*Water Quality Monitoring.* The results of the sediment collection & analysis plan may be used to justify adjustments in sampling (frequency and/or parameter) for the Water Quality Monitoring Plan.	Upon acceptance of sediment quality results by the District.	A copy of the sediment characterization results were submitted to the DEP. At the April 5th meeting, modifications to the water quality monitoring list were discussed.
6	*Protection of Manatees.* At least on person shall be designated as a manatee observer.	When in-water work is being performed.	Done.

Table 3-1 Continued

	Requirements	Due Date	Comments
7	*Removal of Construction Material.* All temporary structures including the mooring facilities and the confined disposal unit, trestle structures, deckling, pilings, etc. shall be removed.	As soon as it is no longer needed for the intended purpose.	Done.
8a	Use best management techniques for erosion and sedimentation control. Silt screens, straw bales, or other sediment control measures are to be used.	At all times during construction.	Silt fences were installed at the CDF site prior to start of construction and were maintained throughout the duration of the project.
8b	All graded areas shall be stabilized and vegetated.	Immediately after construction to prevent erosion.	Done.
9	Inspection Requirements for CDF Berms. Conduct regular inspections of the CDF to ensure its structural ability and submit bi-annual reports to FDEP of inspections of all above ground dikes, levees and berms behind which water is contained. These reports are to include proposal of technique and schedule for repair of any deficiencies noted, and signed and sealed by a register Florida PE.	The first report is due just prior to the operation of the CDF, and every 6 months thereafter until the CDF has been dismantled.	The first report was submitted to FDEP in May 2002. Other reports will be subsequently submitted.
COE Requirements			
1	Reduce and/or eliminate turbid water conditions and the erosion of disturbed or filled areas in adjacent water bodies and wetlands. This is to be achieved through the use of silt curtains or screens between the construction area and wetlands or surface waters during periods of fill placement.	These devices are to be maintained until the disturbed areas become sufficiently stabilized by natural recruitment of vegetation or other measures.	Silt fences were installed at the CDF site prior to start of construction and were maintained throughout the duration of the project.
3a	The Standard Manatee Protection Guidelines should be followed.	During all phases of the project.	Done.
3b	The Notice of Authorization should be displayed at the construction site.		Copy was provided to CDF Construction Contractor.
3c	Notify the District Engineer's representative of the following: (1) date of commencement of work (2) dates of work suspensions and resumptions (if work is suspended over a week) (3) date of final completion.	When work begins.	Done. A fax was sent out to DEP, COE, SFWMD, and Martin County on March 7 indicating that CDF construction was likely to start during the week of March 11.

Table 3-1 Continued

Requirements	Due Date	Comments
Martin County Requirements		
1. Submit to the Martin County Engineering Department signed and sealed drawings document specific information.	At the end of the project.	Done.

4.0 PDS SEDIMENT CHARACTERIZATION

Before the field demonstration could be conducted at the PDS, it was necessary to determine the physical and chemical properties of the site-specific sediments. Sediment physical properties were used to verify that the material removed during dredging matched the fingerprint of the samples taken from the pilot dredging site. Chemical properties of the sediment were used to project water quality impacts that could potentially result from lakebed disturbances due to dredging.

Two rounds of sediment sampling were conducted at the PDS; round 1was initiated during the last week of August 2001 and involved collection of core and bulk sediment samples (Table 4-1). Round 2 was collected just prior to initiation of pilot dredging (April 2002) and included collection of core samples only. During each round, each sample station was located with a handheld Differential Global Positioning System (DGPS) Receiver and assigned a specific project site number and location description.

Sampling was conducted in accordance with the methodology outlined in the *Lake Okeechobee Pilot Dredging Project Sediment Collection & Analysis Plan* (EA, 2001c). The methodology for sample collection, handling, preservation, transport, storage, and analyses was consistent with the guidance contained in the District's Comprehensive Quality Assurance Manual (SFWMD, 1999).

- **Core Samples** – Round 1 included collecting one discrete sediment core from three locations at the pilot dredging site (PDS-01, PDS-02, and PDS-03) (Figure 4-1). In addition, one duplicate Quality Assurance/Quality Control (QA/QC) core (PDS-01 Dup) was also collected from PDS-01. Sampling was conducted using a 3-inch [7.62-cm] (outer diameter) X 48-inch (121.92-cm) long standard TPI AW split spoon sampler manufactured by N&N Drilling Supply Co. of Peckville, PA. The sampler housed a 2½-inch [6.34-cm] (outer diameter) X 48-inch (121.92-cm) long removable clear plastic liner. A pneumatically driven, linear vibra core hammer was used to drive this sampling tool.

  Samples from PDS-01 and PDS-02 were shipped to an analytical laboratory to be analyzed for selected physical and chemical parameters. Sample collected at PDS-03, was analyzed at EA's in-house laboratory to determine basic physical characteristics of the site-specific sediments.

The second round of sediment sampling was conducted prior to the start of the field demonstration (April 2002) and included collection of three in-situ core samples (PDS-04, PDS-05, and PDS-06 (Figure 4-1) to update and confirm site conditions. PDS-04 was collected in the southeast of the dredge area and the other two (PDS-05 and PDS-06) were collected in the northeast of the dredge area. A composite (PDS-Comp-1) was prepared in the laboratory by combining equal parts of the target material and the underlying sediment drawn from aliquots of PDS-04, 05, and 06. This composite was used to develop a baseline that would indicate whether the dredge head was operating deeper than required, i.e. by removing substrate material in additional to the target material.

All three samples were collected using a modified split spoon sampler, which consisted of a 4-ft (1.2-m) acrylic tube that was pushed through the target mud layer until refusal was encountered. At this point, a vacuum was applied and the sample was removed and held on ice. Sediment core samples collected during Round 2 were shipped to Intercounty Laboratories (IL). The upper 30-cm layer (target material) from sediment cores collected at PDS-04, PDS-05, and PDS-06 was analyzed for grain size distribution (sieve and hydrometer), percent organic, bulk density and percent solids by weight only (Table 4-1).

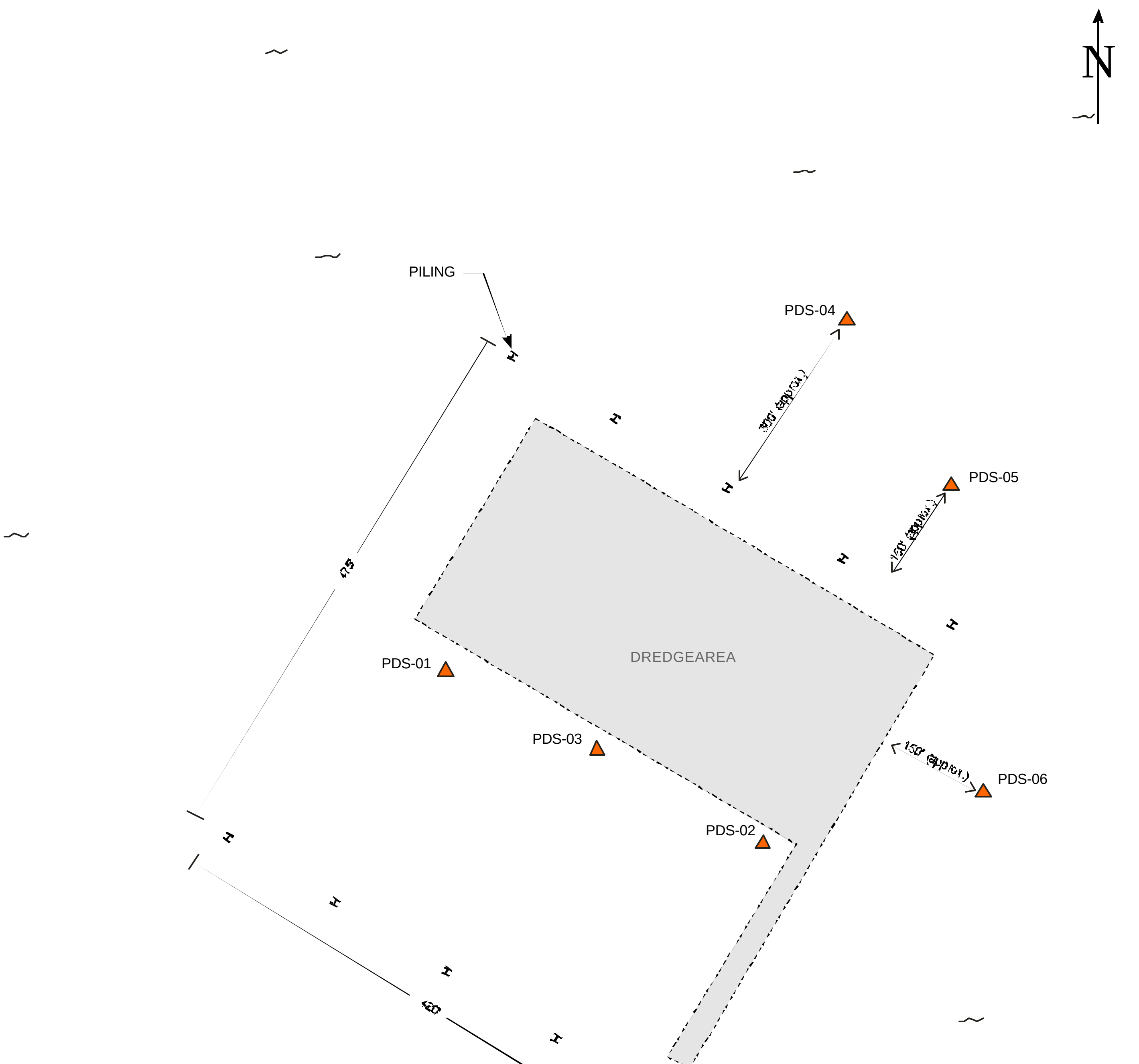
- **Bulk sediment samples** – These were collected during Round 1 only using a hand-manipulated, hydraulic dredging tool. The samples were used to conduct laboratory bench-scale tests to determine engineering properties that were required to design the CDF and the dredged material effluent treatment train.

Additional details of the sampling and analyses of the site-specific sediments can be found in the *Lake Okeechobee Pilot Dredging Project – Sediment Analyses Report* (EA, 2002a).

Table 4-1 Summary of Sediment Core Collection and Target Material Profile

Sample ID	Date of Collection	Sample Collected By	Sample Depth	Grain Size (% Minus No. 200)	Bulk Density (g/cm^3)	% Solids (by wt.)	% Organic[1] (by wt.)	% Water (by wt.)
PDS-01	26-Aug-01	Split Spoon Sampler	0-30 cm	n/a	1.19	19.70	n/a	80.3
PDS-01 Dup	26-Aug-01	Split Spoon Sampler	0-30 cm	n/a	1.20	22.30	n/a	77.7
PDS-02	26-Aug-01	Split Spoon Sampler	0-30 cm	n/a	1.21	22.80	n/a	77.2
PDS-03	26-Aug-01	Split Spoon Sampler	0-10 cm	n/a	1.04	8.00	44.0	92.0
PDS-03[3]			20-30 cm	n/a	1.18	22.00	36.0	78.0
PDS-04	6-May-02	Modifed Split Spoon Sampler[4]	0-30 cm	77.8	n/a	n/a	n/a	n/a
PDS-05	30-May-02	Modifed Split Spoon Sampler[4]	0-30 cm	78.5	1.20	22.00	36.6	78.0
PDS-06	30-May-02	Modifed Split Spoon Sampler[4]	0-30 cm	75.4	1.20	18.50	38.3	81.5
Average[2] (Std. Dev.)			0-30 cm	77.2 (1.33)	1.2 (0.006)	21.06 (1.66)	37.4 (0.85)	78.94 (13.85)
PDS-Comp 1			0-60 cm	49.0	n/a	n/a	n/a	n/a

Note:
n/a = not analyzed
[1] Organic content as a percentage of dry sediments, by weight.
[2] PDS-03 was used to evaluate discrete layers (0-10 cm and 20-30 cm) and was not included in the calculation of the average.
[3] One sample was collected at PDS-03; it was later split in the laboratory into two aliquots for physical analyses.
[4] A modifed split spoon sampler was used to collect these samples.



COREID	DATE	DEVICE
PDS-01	8/26/01	SplitSpoon
PDS-02	8/26/01	SplitSpoon
PDS-03	8/26/01	SplitSpoon
PDS-04	5/8/02	ModifiedSplitSpoon(VacuumLock)
PDS-05	5/30/02	ModifiedSplitSpoon(VacuumLock)
PDS-06	5/30/02	ModifiedSplitSpoon(VacuumLock)

PDS-Comp1 ThissamplewaspreparedinthelaboratorybycombiningequalpartsofthetargetmaterialandunderlyingsedimentdrawnfromPDS-04,05,and06.

DREDGINGDATES5/8/02-5/30/02

NOT-TO-SCALE

EAENGINEERING,SCIENCE, ANDTECHNOLOGY,Inc.	LAKEOKEECHOBEE PILOTDREDGINGPROJECT	DATE: 9-3-02	DRAWNBY:BPG
		JOBNO.: 61507.01	P.M.:AK
		FILENAME: D:/SFWMD/OKEECHOBEE/SSS	

LOCATIONSofPDSSEDIMENTSAMPLINGSTATIONS

FIGURE4-1

4.1 PHYSICAL CHARACTERIZATION

Sediment core profiles are shown in Figure 4-2 and 4-3. Site-specific sediments extracted by cores were observed to be black, organic-rich muds containing shells, showing the presence of entrained gases. The core collected at PDS-03 was divided into sections according to identifiable visual and physical horizons as follows:

- fluid muds -- defined as the fraction with bulk density[3] ($?_w$) ≤ 1.065 g/cm^3
- semi-consolidated muds -- defined as the fraction with bulk density ($?_w$) > 1.065 g/cm^3
- sand substrate -- visual observation
- peat substrate -- visual observation
- beach rock -- visual observation

The target mud layer (roughly the upper 30 cm) of the core was frozen and separated into two layers, 0–10 cm and 10–30 cm. The 10– 20 cm fraction was not analyzed, as it did not show any visually discernable characteristics. No discrete sand layer was observed in the core; the peat and the beach rock sections were discarded following visual observations.

4.1.1 Analysis of the Target Mud Layer

The target mud layer, defined as the upper 30 cm layer of the sediment core, showed distinct differences in the upper horizon (i.e., the fluid muds ranging in depth from 0–10 cm) and lower horizon (i.e., the semi-consolidated layer ranging in depth from 20–30 cm) (Figure 4-2). The semi-consolidated mud layer was determined to begin with the onset of detectable resistance to penetration. Basic physical properties for the two horizons were determined using standard American Society for Testing and Materials (ASTM) test methodology (Table 4-1).

The target mud layer was separated into coarse and fine fractions by wet sieving through a standard No. 200 sieve. Ninety percent (%) (by weight) of this mud portion was shown to be fine-grained. Sieve analyses data were used to generate a particle size distribution profile for the target mud portion of the sediment core (Figure 4-2).

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[3] Lake Okeechobee Phosphorous Dynamics Study, Vol. IX – Sediment Characterization – Resuspension and Deposition, Final 1998-1991, November 1989.

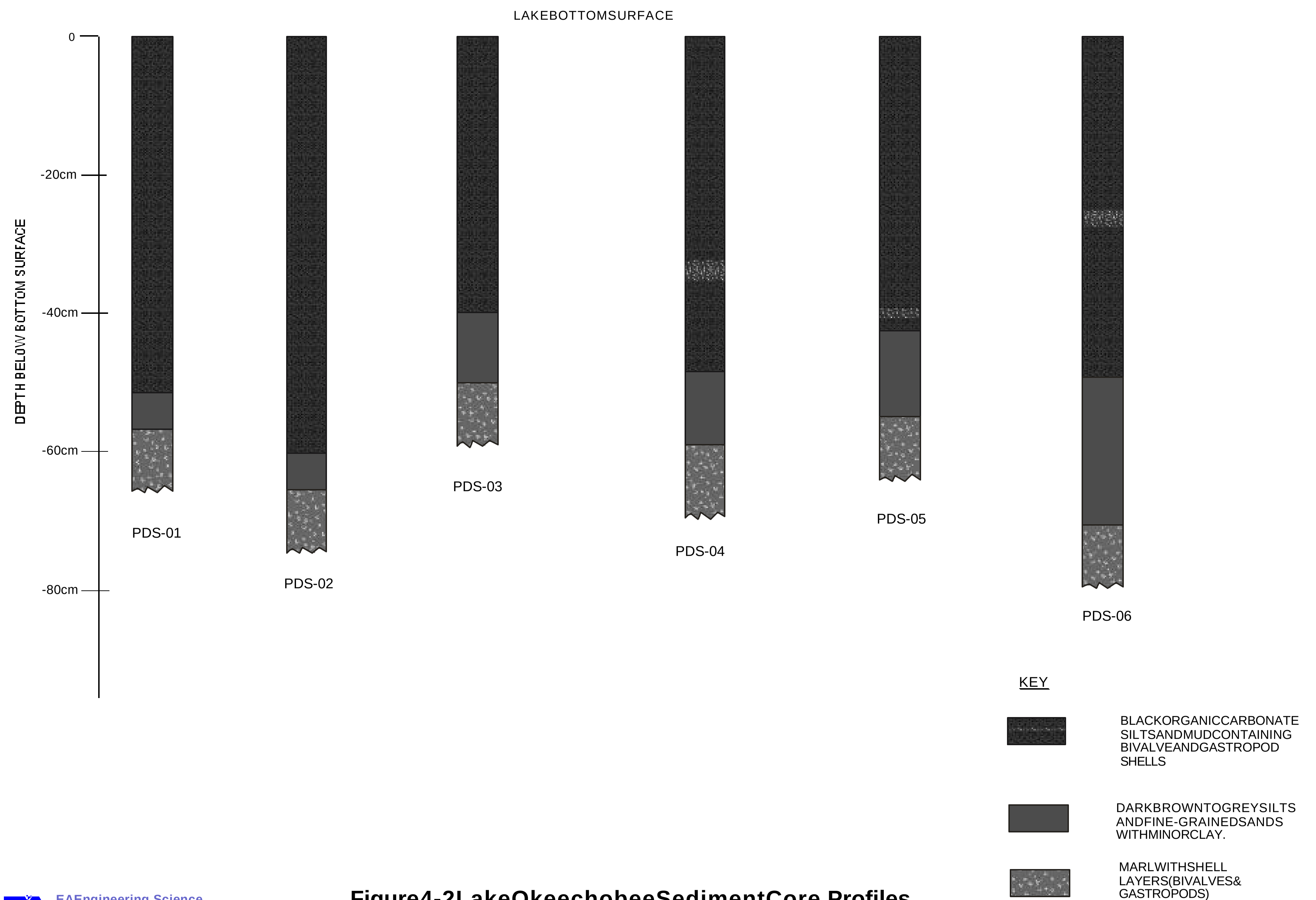

Figure4-2LakeOkeechobeeSedimentCore Profiles

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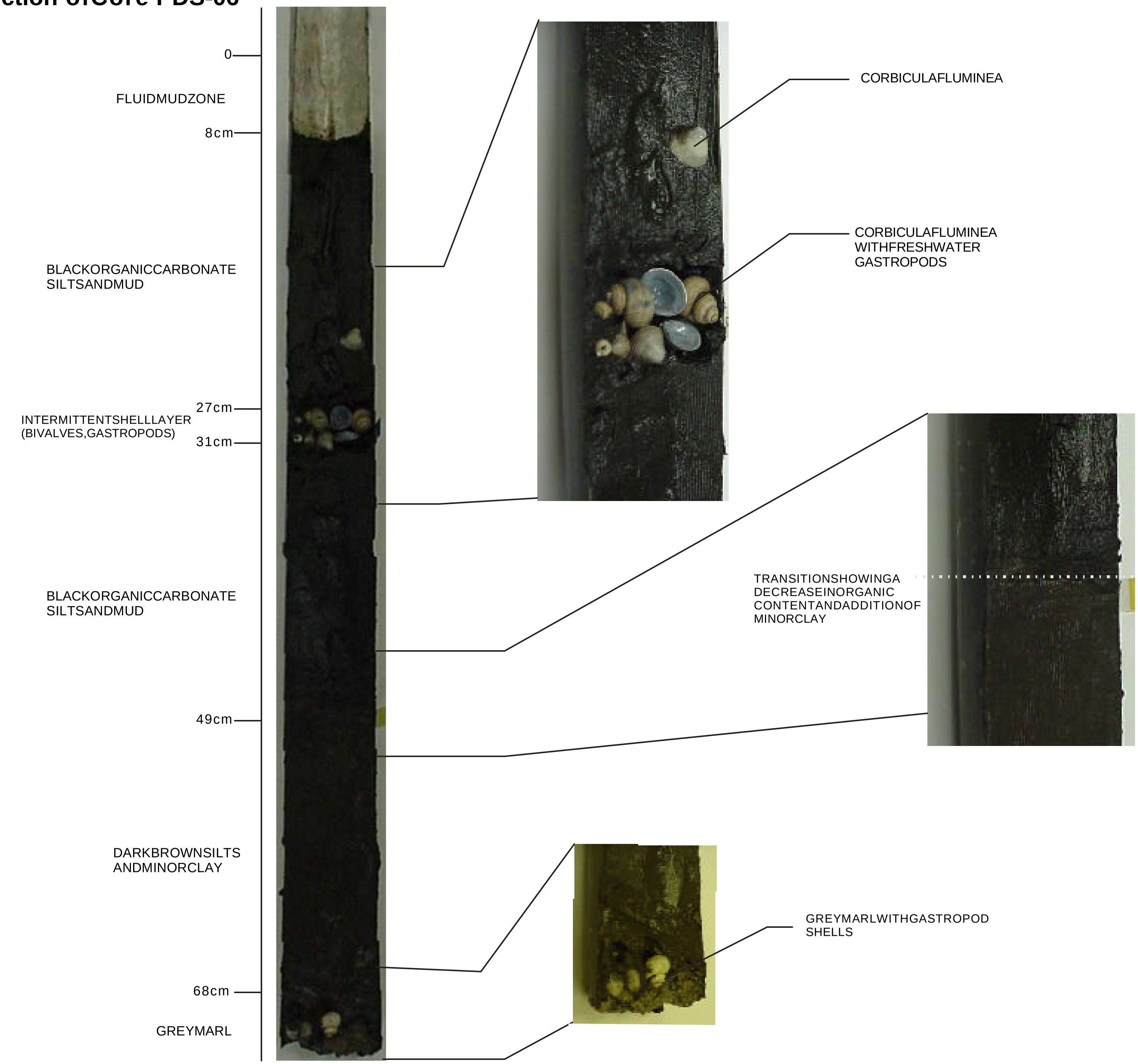
Figure 4-3 Cross Section ofCore PDS-06



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Laboratory analyses indicated that the upper 12 in [30 cm] layer of the mud column (target layer) at the PDS (Table 4-1) was characterized by the following:

- Bulk density values ranged from 1.04 grams/cubic centimeter (g/cm^3) to 1.20 g/cm^3.
- Percentages of solid content by weight ranged from 8% to 22.8%.
- Grain size distribution, which passed the No. 200 sieve, varied from 75.4% to 78.5% (Appendix B, Particle Size Distribution Chart).
- Percentage of organics ranged from 36% to 44%.

Note that average values of bulk density, percent solids content, grain size distribution, and percent organic content of the sediment were calculated based only on samples PDS-01, PDS-01 (Dup), PDS-02, PDS-04, PDS-05, PDS-06.

4.2 CHEMICAL CHARACTERIZATION

Sediment chemical characterization was conducted prior to dredging, and included analyses for selected nutrients, metals, pesticides, and herbicides. Only total mercury concentrations were determined. No clean or ultra trace analyses were conducted for any of the metals.

Nutrients and metals analyses were conducted by PPB Laboratory, Inc. of Gainesville, FL. PPB operates under an FDEP-approved Comprehensive Quality Assurance Plan (CompQAP No. 870017) (PPB, 1994). Samples for pesticides analyses were subcontracted by PPB to Severn Trent Laboratories, Inc. of Tallahassee, FL (FDH # E81005). Sediment pore water samples were extracted and analyzed for selected parameters by the Wetland Biogeochemistry Laboratory of the Institute of Food and Agricultural Sciences (IFAS), University of Florida.

Data Quality Objectives (DQOs) for all chemical analyses were standard QA targets identified in the District CompQAP (1999); these are shown in Table 4-2.

Table 4-2 Project Data Quality Objectives

Parameter	EPA Method No.	Precision (% RSD)	Accuracy (LCL – UCL)	Concentration Range	Method Detection Limit (MDL)
Total Phosphorus	EPA/USACE* (p. 3-227 - 3-229)	0-30 L	50-150	M	1 mg/kg
Dissolved phosphorus (in pore waters)	365.3	0-30 L	80 - 120	M	0.004 mg/l
Orthophosphorus (in pore waters)	365.2	0-10 L	80 - 120	M	0.001 mg/l
Total Nitrogen	Calculated as sum of concentrations of TKN + NO_2 + NO_3				
TKN	EPA/USACE* (p. 3-201 - 3-204)	0-30 H	50-150	M	10 mg/kg
NO_2 + NO_3	EPA/USACE* (p. 3-184 - 3-185)	0-50 L	65-135	M	1 mg/kg
Aluminum	7020	0-60 L	80-120	M	0.5 mg/kg
Arsenic	6010	0-15 L	80-120	L	0.3 mg/kg
Beryllium	6010	0-25 L	80-115	L	0.1 mg/kg
Cadmium	6010	0-50 L	65-135	L	0.1 mg/kg
Chromium	6010	0-40 L	70-130	L	0.1 mg/kg
Copper	6010	0-20 L	80-120	L	0.1 mg/kg
Iron	6010	0-20 L	75-120	L	0.4 mg/kg
Lead	6010	0-50 L	65-125	L	0.3 mg/kg
Mercury	7471	0-30 L	50-140	M	0.10 mg/kg
Nickel	6010	0-30 L	75-120	L	0.2 mg/kg
Selenium	6010	0-15 L	80-120	L	0.2 mg/kg
Silver	7761	0-35 L	65-125	M	0.1 mg/kg
Zinc	6010	0-40 L	75-125	L	0.2 mg/kg
Organophosphorus pesticides	8141	--	--	--	Varies by analyte
Chlorinated pesticides	8081A	--	--	--	Varies by analyte
Chlorinated herbicides	8151	--	--	--	Varies by analyte
Diuron	632/8321	--	--	--	Varies by analyte

Key: LCL = Lower Control Limit; UCL = Upper Control Limit; M = Median Range L = Low Range

*EPA/USACE, Technical Committee on Criteria for Dredged and Fill Material Procedures for Handling and Chemical Analysis of Sediment and Water Samples, May 1981.

4.2.1 Evaluation of Sediment Chemistry Data

All pesticide measurements were below the method detection limit (Table 4-3). Metal concentrations in the site-specific sediment samples were compared to selected sediment screening values derived from existing literature to determine if any of the measured values represented a potential environmental risk (Table 4-4). Note that, because two duplicate samples were collected at PDS01, the two measurements were averaged. The higher of the PDS01mean value and PDS02 value was compared to the chosen sediment screening values.

The following four sources of screening values were used for this comparison:

1. MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000.
2. Smith, S.L, D.D. MacDonald, K.A. Keenleyside, C.G. Ingersoll, and L.J. Field. 1996.
3. MacDonald, D.D. R.S. Carr, F.D. Calder, E.R. Long, and C.G. Ingersoll. 1996.
4. Long, E.R., D. D. MacDonald, S.L. Smith, and F.D. Calder. 1995.

MacDonald et al. (2000) and Smith et al. (1996) both deal with freshwater sediments, and are therefore most appropriate for evaluation of Lake Okeechobee sediments. Data from both MacDonald et al. (1996) and Long et al. (1995) are more relevant to marine and estuarine sediments. However, PDS sediment concentrations were also compared to screening values from both these sources, to determine if conclusions reached through comparison with freshwater screening values were consistent regardless of the screening value source.

Sediment metal concentration were also compared to FDEP soil cleanup target levels (FAC 62-777) to determine if the sediments could be eligible for land application following the completion of the pilot dredging project.

Table 4-3 Chemical Characterization of PDS Sediments (Pesticides)

Analyte	Units	PDS01	PDS01 (QC Duplicate)	PDS02	Method Blank
Carbamate and Urea Pesticides					
Diuron	ug/kg dw	<20Q	<20Q	<19Q	<5.0
Organochlorine Pesticides					
Aldrin	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
alpha-BHC	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
beta-BHC	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
gamma-BHC (Lindane)	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
delta-BHC	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
4,4'-DDT	ug/kg dw	<13Q	<13Q	<13Q	<3.3
Endosulfan I	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
Endosulfan II	ug/kg dw	<13Q	<13Q	<13Q	<3.3
4,4'-DDE	ug/kg dw	<13Q	<13Q	<13Q	<3.3
4,4'-DDD	ug/kg dw	<13Q	<13Q	<13Q	<3.3
Dieldrin	ug/kg dw	<13Q	<13Q	<13Q	<3.3
Endosulfan sulfate	ug/kg dw	<13Q	<13Q	<13Q	<3.3
Endrin	ug/kg dw	<13Q	<13Q	<13Q	<3.3
Endrin aldehyde	ug/kg dw	<13Q	<13Q	<13Q	<3.3
Heptachlor	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
Heptachlor epoxide	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
Toxaphene	ug/kg dw	<650Q	<680Q	<650Q	<170
Endrin ketone	ug/kg dw	<13Q	<13Q	<13Q	<3.3
alpha-Chlordane	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
gamma-Chlordane	ug/kg dw	<6.5Q	<6.8Q	<6.5Q	<1.7
Methoxychlor	ug/kg dw	<65Q	<68Q	<65Q	<17

Table 4-3 Chemical Characterization of PDS Sediments (Pesticides)

Analyte	Units	PDS01	PDS01 (QC Duplicate)	PDS02	Method Blank
Organophosphorus Pesticides					
Dimethoate	ug/kg dw	<260Q	<260Q	<250Q	<66
EPN	ug/kg dw	<130Q	<130Q	<120Q	<33
Ethyl Parathion	ug/kg dw	<130Q	<130Q	<120Q	<33
Malathion	ug/kg dw	<130Q	<130Q	<120Q	<33
Azinphos methyl	ug/kg dw	<260Q	<260Q	<250Q	<66
Bolstar (Sulprofos)	ug/kg dw	<130Q	<130Q	<120Q	<33
Chlorpyrifos	ug/kg dw	<130Q	<130Q	<120Q	<33
Coumaphos	ug/kg dw	<1300Q	<1300Q	<1200Q	<330
Demeton	ug/kg dw	<320Q	<330Q	<320Q	<83
Diazinon	ug/kg dw	<130Q	<130Q	<120Q	<33
Dichlorvos	ug/kg dw	<260Q	<260Q	<250Q	<66
Disulfoton	ug/kg dw	<260Q	<260Q	<250Q	<66
Ethoprop	ug/kg dw	<66Q	<68Q	<65Q	<17
Fensulfothion	ug/kg dw	<1300Q	<1300Q	<1200Q	<330
Fenthion	ug/kg dw	<130Q	<130Q	<120Q	<33
Merphos	ug/kg dw	<130Q	<130Q	<120Q	<33
Methyl parathion	ug/kg dw	<66Q	<68Q	<65Q	<17
Mevinphos	ug/kg dw	<260Q	<260Q	<250Q	<66
Mononcrotophos	ug/kg dw	<1300Q	<1300Q	<1200Q	<330
Naled	ug/kg dw	<1300Q	<1300Q	<1200Q	<330
Phorate	ug/kg dw	<130Q	<130Q	<120Q	<33
Ronnel	ug/kg dw	<130Q	<130Q	<120Q	<33
Stirophos (Tetrachlorvinphos)	ug/kg dw	<130Q	<130Q	<120Q	<33
Sulfotepp (Tetraethyl dithiopyrophosphate)	ug/kg dw	<66Q	<68Q	<65Q	<17
Tokuthion (Prothiofos)	ug/kg dw	<130Q	<130Q	<120Q	<33
Trichloronate	ug/kg dw	<1300Q	<1300Q	<1200Q	<330

Table 4-3 Chemical Characterization of PDS Sediments (Pesticides)

Analyte	Units	PDS01	PDS01 (QC Duplicate)	PDS02	Method Blank
Chlorinated Herbicides					
2,4,5-TP (Silvex)	ug/kg dw	<32Q	<33Q	<32Q	<8.3
2,4-D	ug/kg dw	<32Q	<33Q	<32Q	<8.3
2,4-DB	ug/kg dw	<32Q	<33Q	<32Q	<8.3
2,4,5-T	ug/kg dw	<32Q	<33Q	<32Q	<8.3
Pentachlorophenol	ug/kg dw	<66Q	<68Q	<65Q	<17
Bentazon	ug/kg dw	<140Q	<140Q	<130Q	<35
Dalapon	ug/kg dw	<7800Q	<8000Q	<7600Q	<2000
Dicamba	ug/kg dw	<78Q	<80Q	<76Q	<20
Dichloroprop	ug/kg dw	<390Q	<400Q	<380Q	<100
Dinoseb	ug/kg dw	<390Q	<400Q	<380Q	<100
MCPA[(4-chloro-2-methylphenoxy)-acetic acid]	ug/kg dw	<7800Q	<8000Q	<7600Q	<2000
MCPP[2-(4-chloro-2-methylphenoxy)-propanoic acid]	ug/kg dw	<7800Q	<8000Q	<7600Q	<2000
Picloram	ug/kg dw	<13Q	<13Q	<12Q	<3.3

Q = Samples were extracted and analyzed outside the method required holding time.

Note: While the 14-day holding time was exceeded for these samples; pesticides and herbicides are reasonably stable for much longer than 14 days as long as the samples are maintained at 4 deg C. Under proper storage condutions, for tissues for example, these samples can be held for as long as one year (EPA, 1993). Similar logic would imply that pesticides and herbicides, as long as they are stored appropriatel;y, would safe for analyses beyond the regulatory driven 14-day holding time. As noted in EPA (1995), " ……… holding times for sediments, water, and tissues are based on guidance that is sometimes administrative rather than technical in nature. There are no promulgated, scientifically-based holding time criteria for sediments, tissues, or elutriates. It is our best professional judgement that the exceedance of holding times on these samples should not affect the quality of the pesticide and herbicide analyses.

USEPA, 1993. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Vol 1. Fish Sampling and Analyses. EPA 823-R-93-002

USEPA and USACE. Guidance for Sampling and Analysis of Sediment, Water, and Tissue For Dredged Material Evaluation. EPA823-B-95-001.

Table 4-4 Chemical Characterization of PDS Sediments (Inorganics)

Comparison of sediment concentrations with Sediment Screening Values

Analyte	Matrix	Units	PDSO1	PDSO1 (Duplicate)	PDS01 (Avg)	PDSO2	Max	Freshwater Sediments (Smith et al., 1996)			
								TEL	Exceeds?	PEL	Exceeds?
Moisture Content	Sediment	%	80.30	77.70	79.00	77.20	80.30				
Bulk Density	Sediment	g/cm3	1.188	1.195	1.192	1.210	1.21				
Total Organic Carbon	Sediment	mg/kg	110000.00	220000.00	165000.00	130000.00	220000.00				
Total Kjeldahl Nitrogen	Sediment	mg/kg	10800.00	6900.00	8850.00	6710.00	10800.00				
Nitrate + Nitrite	Sediment	mg/kg	11.70	6.28	8.99	17.10	17.10				
Total Nitrogen	Sediment	mg/L	10800.00	6900.00	8850.00	6730.00	10800.00				
Total Phophorus	Sediment	mg/kg	6400.00	3580.00	4990.00	3870.00	6400.00				
Aluminum	Sediment	mg/kg	5960.00	6820.00	6390.00	6000.00	6820.00				
Arsenic	Sediment	mg/kg	9.20	5.60	7.40	4.40	9.20	5.9	**YES**	17	NO
Beryllium	Sediment	mg/kg	0.9 I	0.6 I	0.75	0.6 I	0.00				
Cadmium	Sediment	mg/kg	1.60	1.00	1.30	0.80	1.60	0.6	**YES**	3.53	NO
Chromium	Sediment	mg/kg	21.10	18.90	20.00	17.20	21.10	37.3	NO	90	NO
Copper	Sediment	mg/kg	17.30	10.90	14.10	11.00	17.30	35.7	NO	193	NO
Iron	Sediment	mg/kg	25400.00	14300.00	19850.00	13200.00	25400.00				
Lead	Sediment	mg/kg	25.60	11.10	18.35	9.40	25.60	35	NO	91.3	NO
Mercury	Sediment	mg/kg	0.50	0.22	0.36	0.21	0.50	0.174	**YES**	0.486	**YES**
Nickel	Sediment	mg/kg	13.90	6.70	10.30	6.00	13.90	18	NO	36	NO
Selenium	Sediment	mg/kg	2.20	1.40	1.80	1.3 U	2.20				
Silver	Sediment	mg/kg	0.10	0.13	0.12	0.11	0.13				
Zinc	Sediment	mg/kg	39.90	22.90	31.40	18.80	39.90	123	NO	315	NO
Soluble Reactive Phophorus	Porewater	mg/L	0.03	0.03	0.03	0.06	0.06				
Total Dissolved Phosphorus	Porewater	mg/L	0.05	0.07	0.06	0.09	0.09				
Ammonium	Porewater	mg/L	4.95	4.25	4.60	3.93	4.95				
Nitrate + Nitrite	Porewater	mg/L	0.04 U	0.04 U	0.04	0.04 U	0.00				

U = Result below detection limit

I = Result between detection limit and practical quantitation limit

TEL = Threshold Effect Level, i.e. the relative concentration below which adverse effects are not expected.

PEL = Probable Effect Level, i.e. the relative concentration above which adverse effects are expected.

ER-L = Effects Range-Low, which represents the 10th percentile of the adverse effect range.

ER-M = Effects Range-Median, which represents the 50th percentile of the adverse effect range.

TEC = Threshold Effect Concentration, i.e. the concentration below which harmfull effects are not expected.

PEC = Probable Effect Concentration, i.e. the concentration above which harmfull effects are expected.

Table 4-4 Chemical Characterization of PDS Sediments (Inorganics)

Comparison of sediment concentrations with Sediment Screening Values

Analyte	Matrix	Units	PDSO1	PDSO1 (Duplicate)	PDS01 (Avg)	PDSO2	Max	FL Coastal Sediments (MacDonald et al.,			
								TEL	Exceeds?	PEL	Exceeds?
Moisture Content	Sediment	%	80.30	77.70	79.00	77.20	80.30				
Bulk Density	Sediment	g/cm3	1.188	1.195	1.192	1.210	1.21				
Total Organic Carbon	Sediment	mg/kg	110000.00	220000.00	165000.00	130000.00	220000.00				
Total Kjeldahl Nitrogen	Sediment	mg/kg	10800.00	6900.00	8850.00	6710.00	10800.00				
Nitrate + Nitrite	Sediment	mg/kg	11.70	6.28	8.99	17.10	17.10				
Total Nitrogen	Sediment	mg/L	10800.00	6900.00	8850.00	6730.00	10800.00				
Total Phophorus	Sediment	mg/kg	6400.00	3580.00	4990.00	3870.00	6400.00				
Aluminum	Sediment	mg/kg	5960.00	6820.00	6390.00	6000.00	6820.00				
Arsenic	Sediment	mg/kg	9.20	5.60	7.40	4.40	9.20	7.24	**YES**	41.6	NO
Beryllium	Sediment	mg/kg	0.9 I	0.6 I	0.75	0.6 I	0.00				
Cadmium	Sediment	mg/kg	1.60	1.00	1.30	0.80	1.60	0.68	**YES**	4.21	NO
Chromium	Sediment	mg/kg	21.10	18.90	20.00	17.20	21.10	52.3	NO	160	NO
Copper	Sediment	mg/kg	17.30	10.90	14.10	11.00	17.30	18.7	NO	108	NO
Iron	Sediment	mg/kg	25400.00	14300.00	19850.00	13200.00	25400.00				
Lead	Sediment	mg/kg	25.60	11.10	18.35	9.40	25.60	30.2	NO	112	NO
Mercury	Sediment	mg/kg	0.50	0.22	0.36	0.21	0.50	0.13	**YES**	0.7	NO
Nickel	Sediment	mg/kg	13.90	6.70	10.30	6.00	13.90	15.9	NO	42.8	NO
Selenium	Sediment	mg/kg	2.20	1.40	1.80	1.3 U	2.20				
Silver	Sediment	mg/kg	0.10	0.13	0.12	0.11	0.13	0.73	NO	1.77	NO
Zinc	Sediment	mg/kg	39.90	22.90	31.40	18.80	39.90	124	NO	271	NO
Soluble Reactive Phophorus	Porewater	mg/L	0.03	0.03	0.03	0.06	0.06				
Total Dissolved Phosphorus	Porewater	mg/L	0.05	0.07	0.06	0.09	0.09				
Ammonium	Porewater	mg/L	4.95	4.25	4.60	3.93	4.95				
Nitrate + Nitrite	Porewater	mg/L	0.04 U	0.04 U	0.04	0.04 U	0.00				

U = Result below detection limit

I = Result between detection limit and practical quantitation limit

TEL = Threshold Effect Level, i.e. the relative concentration below which adverse effects are not expected.

PEL = Probable Effect Level, i.e. the relative concentration above which adverse effects are expected.

ER-L = Effects Range-Low, which represents the 10th percentile of the adverse effect range.

ER-M = Effects Range-Median, which represents the 50th percentile of the adverse effect range.

TEC = Threshold Effect Concentration, i.e. the concentration below which harmfull effects are not expected.

PEC = Probable Effect Concentration, i.e. the concentration above which harmfull effects are expected.

Table 4-4 Chemical Characterization of PDS Sediments (Inorganics)

Comparison of sediment concentrations with Sediment Screening Values

Analyte	Matrix	Units	PDSO1	PDSO1 (Duplicate)	PDS01 (Avg)	PDSO2	Max	NOAA (Long et al., 1995)			
								ER-L	Exceeds?	ER-M	Exceeds?
Moisture Content	Sediment	%	80.30	77.70	79.00	77.20	80.30				
Bulk Density	Sediment	g/cm3	1.188	1.195	1.192	1.210	1.21				
Total Organic Carbon	Sediment	mg/kg	110000.00	220000.00	165000.00	130000.00	220000.00				
Total Kjeldahl Nitrogen	Sediment	mg/kg	10800.00	6900.00	8850.00	6710.00	10800.00				
Nitrate + Nitrite	Sediment	mg/kg	11.70	6.28	8.99	17.10	17.10				
Total Nitrogen	Sediment	mg/L	10800.00	6900.00	8850.00	6730.00	10800.00				
Total Phophorus	Sediment	mg/kg	6400.00	3580.00	4990.00	3870.00	6400.00				
Aluminum	Sediment	mg/kg	5960.00	6820.00	6390.00	6000.00	6820.00				
Arsenic	Sediment	mg/kg	9.20	5.60	7.40	4.40	9.20	8.2	**YES**	70	NO
Beryllium	Sediment	mg/kg	0.9 I	0.6 I	0.75	0.6 I	0.00				
Cadmium	Sediment	mg/kg	1.60	1.00	1.30	0.80	1.60	1.2	**YES**	9.6	NO
Chromium	Sediment	mg/kg	21.10	18.90	20.00	17.20	21.10	81	NO	370	NO
Copper	Sediment	mg/kg	17.30	10.90	14.10	11.00	17.30	34	NO	270	NO
Iron	Sediment	mg/kg	25400.00	14300.00	19850.00	13200.00	25400.00				
Lead	Sediment	mg/kg	25.60	11.10	18.35	9.40	25.60	46.7	NO	218	NO
Mercury	Sediment	mg/kg	0.50	0.22	0.36	0.21	0.50	0.15	**YES**	0.71	NO
Nickel	Sediment	mg/kg	13.90	6.70	10.30	6.00	13.90	20.9	NO	51.6	NO
Selenium	Sediment	mg/kg	2.20	1.40	1.80	1.3 U	2.20				
Silver	Sediment	mg/kg	0.10	0.13	0.12	0.11	0.13	1	NO	3.7	NO
Zinc	Sediment	mg/kg	39.90	22.90	31.40	18.80	39.90	150	NO	410	NO
Soluble Reactive Phophorus	Porewater	mg/L	0.03	0.03	0.03	0.06	0.06				
Total Dissolved Phosphorus	Porewater	mg/L	0.05	0.07	0.06	0.09	0.09				
Ammonium	Porewater	mg/L	4.95	4.25	4.60	3.93	4.95				
Nitrate + Nitrite	Porewater	mg/L	0.04 U	0.04 U	0.04	0.04 U	0.00				

U = Result below detection limit

I = Result between detection limit and practical quantitation limit

TEL = Threshold Effect Level, i.e. the relative concentration below which adverse effects are not expected.

PEL = Probable Effect Level, i.e. the relative concentration above which adverse effects are expected.

ER-L = Effects Range-Low, which represents the 10th percentile of the adverse effect range.

ER-M = Effects Range-Median, which represents the 50th percentile of the adverse effect range.

TEC = Threshold Effect Concentration, i.e. the concentration below which harmfull effects are not expected.

PEC = Probable Effect Concentration, i.e. the concentration above which harmfull effects are expected.

Table 4-4 Chemical Characterization of PDS Sediments (Inorganics)

Comparison of sediment concentrations with Sediment Screening Values

Analyte	Matrix	Units	PDSO1	PDSO1 (Duplicate)	PDS01 (Avg)	PDSO2	Max	Freshwater TEC (MacDonald et al., 2000)			
								TEC	Exceeds?	PEC	Exceeds?
Moisture Content	Sediment	%	80.30	77.70	79.00	77.20	80.30				
Bulk Density	Sediment	g/cm3	1.188	1.195	1.192	1.210	1.21				
Total Organic Carbon	Sediment	mg/kg	110000.00	220000.00	165000.00	130000.00	220000.00				
Total Kjeldahl Nitrogen	Sediment	mg/kg	10800.00	6900.00	8850.00	6710.00	10800.00				
Nitrate + Nitrite	Sediment	mg/kg	11.70	6.28	8.99	17.10	17.10				
Total Nitrogen	Sediment	mg/L	10800.00	6900.00	8850.00	6730.00	10800.00				
Total Phophorus	Sediment	mg/kg	6400.00	3580.00	4990.00	3870.00	6400.00				
Aluminum	Sediment	mg/kg	5960.00	6820.00	6390.00	6000.00	6820.00				
Arsenic	Sediment	mg/kg	9.20	5.60	7.40	4.40	9.20	9.79	NO	33	NO
Beryllium	Sediment	mg/kg	0.9 I	0.6 I	0.75	0.6 I	0.00				
Cadmium	Sediment	mg/kg	1.60	1.00	1.30	0.80	1.60	0.99	**YES**	4.98	NO
Chromium	Sediment	mg/kg	21.10	18.90	20.00	17.20	21.10	43.4	NO	111	NO
Copper	Sediment	mg/kg	17.30	10.90	14.10	11.00	17.30	31.6	NO	149	NO
Iron	Sediment	mg/kg	25400.00	14300.00	19850.00	13200.00	25400.00				
Lead	Sediment	mg/kg	25.60	11.10	18.35	9.40	25.60	35.8	NO	128	NO
Mercury	Sediment	mg/kg	0.50	0.22	0.36	0.21	0.50	0.18	**YES**	1.06	NO
Nickel	Sediment	mg/kg	13.90	6.70	10.30	6.00	13.90	22.7	NO	48.6	NO
Selenium	Sediment	mg/kg	2.20	1.40	1.80	1.3 U	2.20				
Silver	Sediment	mg/kg	0.10	0.13	0.12	0.11	0.13				
Zinc	Sediment	mg/kg	39.90	22.90	31.40	18.80	39.90	121	NO	459	NO
Soluble Reactive Phophorus	Porewater	mg/L	0.03	0.03	0.03	0.06	0.06				
Total Dissolved Phosphorus	Porewater	mg/L	0.05	0.07	0.06	0.09	0.09				
Ammonium	Porewater	mg/L	4.95	4.25	4.60	3.93	4.95				
Nitrate + Nitrite	Porewater	mg/L	0.04 U	0.04 U	0.04	0.04 U	0.00				

U = Result below detection limit

I = Result between detection limit and practical quantitation limit

TEL = Threshold Effect Level, i.e. the relative concentration below which adverse effects are not expected.

PEL = Probable Effect Level, i.e. the relative concentration above which adverse effects are expected.

ER-L = Effects Range-Low, which represents the 10th percentile of the adverse effect range.

ER-M = Effects Range-Median, which represents the 50th percentile of the adverse effect range.

TEC = Threshold Effect Concentration, i.e. the concentration below which harmfull effects are not expected.

PEC = Probable Effect Concentration, i.e. the concentration above which harmfull effects are expected.

Table 4-4 Chemical Characterization of PDS Sediments (Inorganics)

Comparison of sediment concentrations with Soil Cleanup Target Levels (FAC 62-777)

Analyte	Units	PDSO1	PDSO1 (Duplicate)	PDS01 (Avg)	PDSO2	Max	Soil Cleanup Target Levels (FAC 62-777)			
							Residential	Exceeds?	Industrial	Exceeds?
Moisture Content	%	80.30	77.70	79.00	77.20	79.00				
Bulk Density	g/cm3	1.19	1.20	1.19	1.21	1.21				
Total Organic Carbon	mg/kg	110000.00	220000.00	165000.00	130000.00	165000.00				
Total Kjeldahl Nitrogen	mg/kg	10800.00	6900.00	8850.00	6710.00	8850.00				
Nitrate + Nitrite	mg/kg	11.70	6.28	8.99	17.10	17.10				
Total Nitrogen	mg/L	10800.00	6900.00	8850.00	6730.00	8850.00				
Total Phophorus	mg/kg	6400.00	3580.00	4990.00	3870.00	4990.00				
Aluminum	mg/kg	5960.00	6820.00	6390.00	6000.00	6390.00	72000.00	NO		
Arsenic	mg/kg	9.20	5.60	7.40	4.40	7.40	0.80	**YES**	3.70	**YES**
Beryllium	mg/kg	0.9 I	0.6 I	0.75	0.6 I	0.75	120.00	NO	800.00	NO
Cadmium	mg/kg	1.60	1.00	1.30	0.80	1.30	75.00	NO	1300.00	NO
Chromium	mg/kg	21.10	18.90	20.00	17.20	20.00	210.00	NO	420.00	NO
Copper	mg/kg	17.30	10.90	14.10	11.00	14.10	110.00	NO	76000.00	NO
Iron	mg/kg	25400.00	14300.00	19850.00	13200.00	19850.00	23000.00	NO	480000.00	NO
Lead	mg/kg	25.60	11.10	18.35	9.40	18.35	400.00	NO	920.00	NO
Mercury	mg/kg	0.50	0.22	0.36	0.21	0.36	0.80	NO	5.40	NO
Nickel	mg/kg	13.90	6.70	10.30	6.00	10.30	110.00	NO	28000.00	NO
Selenium	mg/kg	2.20	1.40	1.80	1.3 U	1.80	390.00	NO	10000.00	NO
Silver	mg/kg	0.10	0.13	0.12	0.11	0.12	390.00	NO	9100.00	NO
Zinc	mg/kg	39.90	22.90	31.40	18.80	31.40	23000.00	NO	560000.00	NO
Soluble Reactive Phophorus	mg/L	0.03	0.03	0.03	0.06	0.06				
Total Dissolved Phosphorus	mg/L	0.05	0.07	0.06	0.09	0.09				
Ammonium	mg/L	4.95	4.25	4.60	3.93	4.60				
Nitrate + Nitrite	mg/L	0.04 U	0.04 U	0.04	0.04 U	0.04				

U = Result below detection limit

I = Result between detection limit and practical quantitation limit

4.2.2 Discussion

Smith et al. (1996) and MacDonald et al. (1996) proposed the concept of **Threshold Effect Levels (TEL)** and **Probable Effect Levels (PEL)**, which are reflective of concentrations below which adverse effects are not expected (TEL), or above which adverse effects are expected (PEL). Analogous terms found in Long et al. (1995) are the **Effects Range-Low (ER-L)** and **Effects Range-Median (ER-M)**, which represent the 10^{th} and 50^{th} percentile of adverse effect range data respectively.

MacDonald et al. (2000) integrated many of the existing publications on freshwater sediment toxicity, and reevaluated the selection process to develop what was termed the **consensus screening value**. Two concepts were proposed by the authors; the **Probable Effect Concentrations (PEC)**, which are intended to identify contaminant concentrations above which harmful effects on sediment-dwelling organisms are expected, and the **Threshold Effect Concentrations (TEC)**, which were defined as concentrations below which harmful effects on sediment-dwelling organisms are not expected.

Significant observations from physical and chemical characterization of PDS sediments are presented in Chapter 9.

4.3 BENCH-SCALE TESTING

The primary objectives of the sediment bench-scale testing program were:

1. To obtain information on the settling and consolidation properties of the site-specific sediments, and
2. To evaluate alternative sediment dewatering and water-treatment technologies.

Bench-scale tests were conducted at EA's in-house laboratory using aliquots of bulk sediment samples collected in August 2001. A second round of bulk sediment sampling was conducted in January 2002, to provide additional volumes needed to complete the testing. Note that aliquots of only the fluid-mud fraction of the sediment column were used in these tests. In addition to testing conducted at EA's in-house laboratory, portions of the bulk sediment samples were also shared with two commercial vendors to demonstrate effectiveness of their water-treatment technologies.

The bench-scale testing program included the following tests:

Column Settling and Flocculent Settling Tests – were conducted to evaluate the rate at which solids in a simulated dredged slurry would separate from the liquid phase and settle at the bottom. The testing was conducted using an 8 in [20 cm] inner diameter x 8½ ft [2.6 m] in height settling column, which was loaded with an aliquot of the site-specific mock dredge slurry with a solids concentration of 159 g/L. Aliquots used for the settling test consisted of fine-grained material (less than No. 200 sieve). Coarse-grained (greater than No. 200 sieve) material present in the sample was hydraulically separated prior to introducing the sample into the settling column. Compressed air was introduced from the bottom of the column to put the mixture into a uniform suspension. Once the mixture was thoroughly mixed, the air supply was shut off and the sample was allowed to undergo natural settling. Slurry was allowed to settle until the interface level was of sufficient depth to allow sample collection without disturbing the interface.

Settling test data indicated that it would take up to 2 days of undisturbed natural settling in a CDF to produce a supernatant in the 40 to 50 mg/L range TSS that could then be used as a feedstock for a water treatment process aimed at reducing total phosphorus concentrations.

Compression Tests – were conducted in parallel with the column settling tests to measure the volume associated with the solids layer after settling occurs. Compression test measurements were obtained during the column settling test by recording the interface height and average solids concentration over a period of 15 days. Slurry concentrations for various interface heights were calculated mathematically. The interface heights were plotted against time to develop a height vs. time curve and the average solids concentration was plotted against time to determine the compression settling rate. Test data indicates that compression settling started after approximately 9 days, when the average solid concentration reached approximately 270 g/L.

Column Consolidation Test - This test provided information on the consolidation (i.e. compaction) properties of the simulated dredged slurry. Two separate scenarios (single drainage to the top and double drainage to top and bottom) were evaluated. Test results indicated that double drainage failed to improve the consolidation properties of the mass, and single drainage towards the surface was the predominant drainage mode leading to sediment consolidation.

Chemical Clarification Tests – were used to determine effectiveness of various coagulants, flocculants, and/or polymers to treat the water that separates from the dredged material (supernatant or dredging effluent). These tests provided information on the most effective chemical to be used in treating the supernatant water; optimum dosage; optimum feed concentration; effects of dosage on removal efficiencies; effects of influent contaminant concentrations on removal efficiencies; effects of mixing conditions; and effects of settling times. Testing was aimed at reducing TSS concentrations to the lowest possible level (=29 NTU) and total phosphorus concentrations to below 40 ug/L.

Since zone settling properties of the primary effluent had previously shown that the supernatant naturally achieved low TSS concentration within 48 hours of settling (40 to 50 mg/L), the clarification tests focused on reducing total phosphorus concentrations. Testing involved subjecting the supernatant to chemical precipitation followed by treatment with an anionic polymer as described below.

Chemical Precipitation Tests – The objective of this testing was to evaluate the effectiveness of using a coagulant and a flocculating agent in reducing total phosphorus concentrations in the supernatant to below 40 µg/L. Pros and cons of several different chemical agents were evaluated including use of alum and ferric salts, both of which have been previously shown to be effective in reducing total phosphorus concentrations to below 40 ug/L. Use of alum salts was ruled out due to potential for biotoxicity and it was concluded that iron (III) chloride hexahydrate (97%, A.C.S. reagent $FeCl_3 \bullet 6H_20$) was the most suitable coagulant for the chemical precipitation tests. NALCLEAR 8184 (a high molecular weight polymer), manufactured by Nalco Chemical Company was selected as the flocculating agent. A target Fe:P molar ratio of 145:1 was selected based on previous District study[3].

Dewatering With Geotubes – Geotextile fabric GeoTex 1016T (apparent opening size was less than the #50 sieve) was evaluated for ability to dewater the simulated dredged materials. A four feet high column was prepared by mounting a sample of the test filter fabric at the base of a vertical tube. Mock slurry with a TSS concentration of 131 g/L was poured into the column and the total height of the slurry and the volume of filtrate passing the fabric membrane were measured at 0 hours, 1 hour, 3 hours, 6 hours, 12 hours, and 18 hours. The initial flow rate of the filtrate across the filter fabric was measured as 2.2 ml/hour/cm^2. After the first hour, the flow across the filter had decreased to 0.5 ml/hour/cm^2. After 12 hours, the flow across the

[3]Chemical Treatment Followed by Solids Separation Advanced Technology Demonstration Project." Final Report prepared by HAS Engineers & Scientists for the South Florida Water Management District (Contract # E10650). Dec 2000.

membrane ceased due to the development of an impermeable filter cake on the filter fabric. It was therefore concluded that Geotubes using this filter fabric would not be suitable for dewatering Lake Okeechobee sediment slurries.

Silica Micro Encapsulation Test (conducted by KEECO, Inc.) – The objective of this testing was to determine the effectiveness of the Silica Micro Encapsulation (SME) process to reduce phosphorus levels in a simulated dredge effluent. The SME technology – patented by Klean Earth Environmental company (KEECO) of Lynwood, WA, had been previously shown to be very effective in reducing contaminant concentrations in waters and sediments by as much as three orders of magnitude. Testing involved treating mock effluent samples with the patented additive(s) and testing total phosphorus concentrations before and after the addition. The additives work by encapsulating contaminant molecules in an inert matrix resulting in a product that is permanently stable and impervious to environmental degradation. Test results indicated the SME additive was very effective in reducing total phosphorus concentrations to below 40 ug/L.

Results of the bench-scale tests were used to finalize the engineering design of the CDF and develop a conceptual design for the pilot water treatment system.

Additional details on the methodology used during bench-scale testing and test results are contained in the *Lake Okeechobee Pilot Dredging Project – Bench Scale Testing Report* (EA, 2002b). Significant observations from the bench-scale testing are presented in Chapter 9.

5.0 PILOT DREDGING

5.1 INTRODUCTION

Prior to starting the field demonstration, the PDS was delineated by installing ten steel H-piles, 40 ft [12.19 m] in length, in a NW/SE direction offset from the northern and southern boundaries of the PDS. The pilings were installed in two parallel rows at 105 ft [32 m] spacing: five along the northern and five along the southern boundary. The pilings were marked with caution signs and were provided with flashing lights in accordance with the U.S. Coast Guard (USCG) aids to navigation requirements. Manatee warning signs were also posted at the PDS and CDF to ensure that the mammals were adequately protected if they happen to enter the work area.

The dredging operations, initially planned for 10 days, were extended to 23 days (May 12 to May 29, 2002) due to unforeseen weather and wave conditions that required additional equipment and manpower to provide a safe working environment. The hull size of the prototype dredge (26 ft x 8 ft [7.9 m x 2.4 m]) and the associated floating transfer lines—compared to what would be used for a full-scale dredging operation needed for Lake Okeechobee—left the operation notably vulnerable to rough lake conditions. Moreover, due to Lake Okeechobee's large size and very shallow depth significant wave action can quickly build up under even moderate winds. Wave heights of 2 ft – 4 ft [0.6 m–1.2 m] occurred regularly with wind velocities ranging from 12 kts – 20 kts. These conditions prevailed throughout most of the operating period. Sustained winds below 12 kts were only observed in three of the 23 days of the dredging operations. These lake conditions made operation of the dredge and adjustments for the position of the travel cables to which the dredge was attached both difficult and, at times, dangerous. Thirteen days were either lost entirely or consumed in dealing with the effects of these conditions. Table 5-1 summarizes activities undertaken during each workday of the field demonstration.

To safely and reliably operate the dredge and associated transfer lines, we found it necessary to obtain and position three large spud barges (platform barges equipped with two anchor pilings). The spud barges were approximately 120 ft x 35 ft [36.6 m x 10.7m] (Figure 5-1). The spud barges were positioned to block the winds and seas, enabling the crew to safely operate the dredge in a relatively calm lee. These conditions, deemed unsafe by the project Health and Safety Officer, forced the suspension of dredging on multiple days. A crane also was brought to the PDS to allow the daily removal of the dredge and floating lines. A typical arrangement of these barges to counter the predominant northeasterly wind is illustrated in Figure 5-1.

Table 5-1 Summary of Field Activities

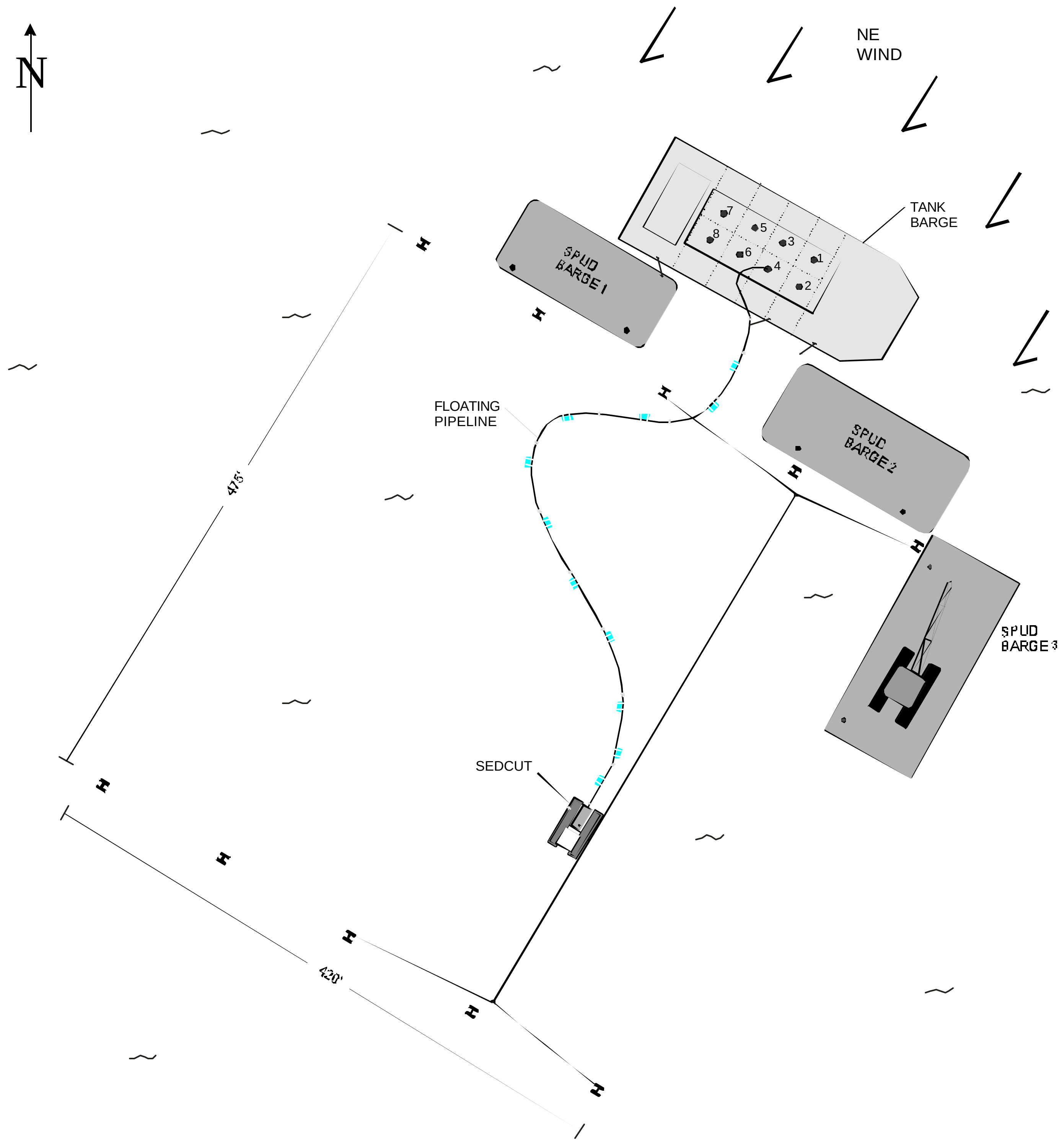
Date	Day	Pilot Dredging Day No.	Tasks Undertaken/Completed
5/2/02	Thursday		Tanker Barge preparation
5/3/02	Friday		Tanker Barge preparation
5/4/02	Saturday		Shut Down
5/5/02	Sunday		Set Pilings/ Gulf on-site
5/6/02	Monday		Tanker Barge preparation/ Mobilized Sedcut to Maritime's Yard
5/7/02	Tuesday		Collected pre-dredge water quality samples/Sedcut Preparation
5/8/02	Wednesday		Tanker Barge preparation/ Sedcut preparation
5/9/02	Thursday		Set cable system up at dredge site/Mobilized sedcut to dredge site
5/10/02	Friday		Mobilized Crane Barge to CDF, Tanker Barge to Dredge site/started pipeline assembly
			Shut down at 3 pm due to weather
5/11/02	Saturday		Lost 350-ft of pipeline due to weather- recovered 120 ft
			Shut down operations due to weather
5/12/02	Sunday	Day 1	Mobilized Crane barge to dredge site - completed pipeline installation
			Conducted first dredge run in SE quadrant (lane 400 -mouth opening 2"),
			Shut down after 35 min due to pipeline coupling failures - wave action broke hose clamps
			Demobilized from dredge site to strengthen pipeline connections
5/13/02	Monday		SFWMD Representatives on-site.
			Modified pipeline connections
5/14/02	Tuesday		Mobilized pipeline to dredge site and connected to dredge unit
			Mobilized large spud barge to dredge site - to serve as wave protection
5/15/02	Wednesday		Shut Down operations due to high seas - removed floating pipeline
5/16/02	Thursday		High seas damaged dredge unit cabling system
			Repaired dredge cabling system
			Mobilized 2nd spud barge to dredge area
			Positioned spud barges and crane barge to block a SE wind
			Installed 350 ft of pipeline
5/17/02	Friday	Day 2	Winds shifted overnight from the SE to the East
			Dredge unit and pipline were damaged from 2-3 ft waves
			Removed pipeline -repaired damage to dredge unit ballast tanks
			Reconfigured spud barges to block a East wind- re-installed pipeline
			Started dredge operations at 3:50 and ran unit 5:30
			Shut down operations and left dredge site with cargo barge at 7 pm
			Arrived at CDF at 8 :30 pm and tested off-loading operations with Boom truck
			Shut down operations at 9 pm
5/18/02	Saturday		Arrive at CDF at 7 am and started off-loading operations
			Completed off-loading operations at 12 pm and mobilized cargo barge to dredge site
			Configure spud barges and crane barge to block a SE wind and secured pileline
			Shut down operations at 3 pm
5/19/02	Sunday		Arrived on-site at 6:30; decided to shut down operations at 10:00 am due to heavy winds
			High winds prevented use of crane
5/20/02	Monday	Day 3	Arrived at dredge site at 7:30; pipeline damaged - winds shifted overnight to the N-NE
			Reconfigured barges to block a n-NE wind
			Started dredge operations around 4 pm and shut down at 7 pm
5/21/02	Tuesday	Day 4	Started dredge operations and filled cargo barge to max draft limit
			Shut down operations at 7 pm
5/22/02	Wednesday		High seas and winds, Tug grounded cargo barge in channel
5/23/02	Thursday		Shut down due to high seas and returned to CDF
5/24/02	Friday	Day 5	Mobilized equipment and started dredge operations
			Filled cargo barge and removed all equipment and pipeline
			Unloaded cargo barge
5/25/02	Saturday	Day 6	Conducted dredging operations
5/26/02	Sunday		Shut Down
5/27/02	Monday	Day 7	Conducted dredging operations
5/28/02	Tuesday	Day 8	Conducted dredging operations
5/29/02	Wednesday	Day 9	Completed operations
5/30/02	Thursday		Off-loaded Tanker barge at CDF

The time required for daily repositioning of these barges to accommodate varying wind intensity and direction, daily demobilization and setup of the dredge and floating lines, and the added transit time for towing the cargo barge to and from the 5 mile [8.05 km] offshore PDS, significantly added to the operational delays, the effort and the cost of the operation compared to the original plan.

A key element of this study was to determine the degree to which the equipment and techniques employed during this pilot study can be efficiently scaled up to support full-scale sediment dredging of the Lake (if that option is chosen by the District). The weather impacts observed during the pilot test would be significantly reduced with full-scale equipment. EA believes the design of the dredge head used in this operation is intrinsically scalable, both to larger physical size (width of opening) and to larger pumping capacity (see Section 9).

The depth of the SEDCUT® dredge head was determined by lowering the unit down until the support cable showed no visible signs of tension. This was determined by observing slack in the cable line. Once slack was detected in the support cable, the cable was locked into position, allowing the unit to rest on the denser substrate. In order for the unit to slide along an irregular bottom, the unit was equipped with a vertical freedom hinge to provide 1ft [0.3 m] of vertical movement. Due to the lake state conditions encountered (2 – 3 ft [0.6m – 0.9m] waves) and the lack of clarity of the water just above the fluid mud layer, underwater cameras could not provide visual confirmation on the unit's position in the vertical hinge (top or bottom part of hinge).

The unit was equipped with two ballast tanks sized to reduce the unit contact pressure to allow the unit to rest on top of the denser substrate. The ballast tanks remained empty throughout the project and were flooded on the last lane cut to evaluate the effects of increasing the unit's weight. After the ballast tanks were flooded the additional weight allowed the unit to be lowered an additional 0.9 ft [0.27m] deeper than the previous lane cut.



SEDCUT-8ftx26ft(2.4mx7.9m)

SPUDBARGE-35ftx120ft(10.7mx36.6m)

TANKBARGE-40ftx165ft(12.2mx50.3m)

EAENGINEERING,SCIENCE,
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LAKEOKEECHOBEE
PILOTDREDGINGPROJECT

Not-to-Scale

DATE: 6-26-02	DRAWNBY: BPG
JOBNO.: 61507.01	P.M.: A.K.
FILENAME: D:/SFWMD/LAKEO/SITE	

TYPICALBARGEARRANGEMENT

FIGURE5-1

5.2 EQUIPMENT SPECIFICATIONS

5.2.1 Dredge Head Design

The SEDCUT® dredge head design was based on the concept of a bottom-contact sliding dredge head fitted with a submersible pump. The unit was designed to selectively remove a relatively thin layer of mud from the bottom of Lake Okeechobee with minimum pickup of the denser substrate that supports this mud layer. In addition, the dredge head was configured so that a minimal amount of dilution water from the overlying water column would be collected by the submersible pump. The general principle was to feed the mud layer into the inlet of the pump by adjusting the forward travel rate of the dredge head through an adjustable inlet frontal area (i.e. mouth opening) so that the pump's discharge rate would be equal to or less than the gathering rate of the head. The dimension of the inlet area for the dredge head was designed so that a very slow rate of advance would occur during the dredging process, to minimize the resuspension of the mud layer. Figures 5-2 through 5-4 show schematics of the dredge head.

Design of the dredge head connection to the pivoting arm permitted the head some degree of vertical freedom so that it could slide on and follow the denser substrate underlying the mud layer. To enable the unit to maintain a horizontal advancement path, a series of skis were attached to the lower lip of the mouth opening to prevent the unit from digging into the underlying substrate. The following design considerations were utilized:

1. **Contact Pressure:** The ability to vary the dredge head contact pressure was part of the original design concept, utilizing variable buoyancy tanks. Bench-scale tests using core samples obtained from the PDS revealed that the underlying substrate had measurable, consistent, but very low shear strength values (0.10 pounds per square inch (psi) [7.03 g/cm^2] to 0.24 psi [16.88 g/cm^2]). Accordingly, variable buoyancy ballast tanks were sized to reduce the unit's contact pressure to this range.

2. **Intake Visor:** To vary the vertical height of the intake opening, an adjustable intake visor was installed at the top of the mouth area. The visor was designed to allow the intake opening to adjust from 12 in [30.48 cm] (100% of the mud layer thickness) to 2 in [5.08 cm] (16% of the mud layer thickness).

3. **Pumping system:** A 6 in [15 cm] discharge diameter hydraulic-drive submersible pump, capable of delivering a maximum flow rate of 1,500 gpm [5678.12 L/min], was mounted aft on the dredge head. The projected output of the overall pumping system applied to the specific site conditions for the demonstration project would be as follows:

Static lift at dredge head	12 ft [3.66 m]
Terminal lift at tank barge	8 ft [2.44 m]
500 ft [152 m] of pipeline friction 5.2 ft/100 ft (with a dredge slurry of 1.1)	26 ft [7.92 m]
Elbows and couplings	10 ft [3.05 m]
Total Dynamic Head	56 ft [17.07m]

The manufacturer's pump curve shows that the pump would have a flow rate of approximately 1,300 gpm [4,921 L/min] at 56 ft [17.07 m] Total Dynamic Head (TDH).

4. **Advance rate:** The travel rate calculations were based on a constant pump rate of 1,300 gpm [4,921 L/min] and the assumption that the volume of material in a 6 ft [1.82 m] wide swath removing a 1 ft [0.3 m] thick mud layer would remain constant. However, since the mud has extremely low shear strength values and behaves as a fluid, it is believed that a 6 ft [1.83 m] opening width would influence a swath width greater than 6 ft [1.83 m]. Therefore, the following calculated travel rate is estimated to be the maximum limit for a 12 in [30.48 cm] dredge head intake opening.

1,300 gpm/7.48 gals/ft^3 =173 ft^3/min [4.9 m^3/min]
173 ft^3/min/(6 ft x 1 ft, i.e. frontal area) = 28.8 ft/min [9 m/min]

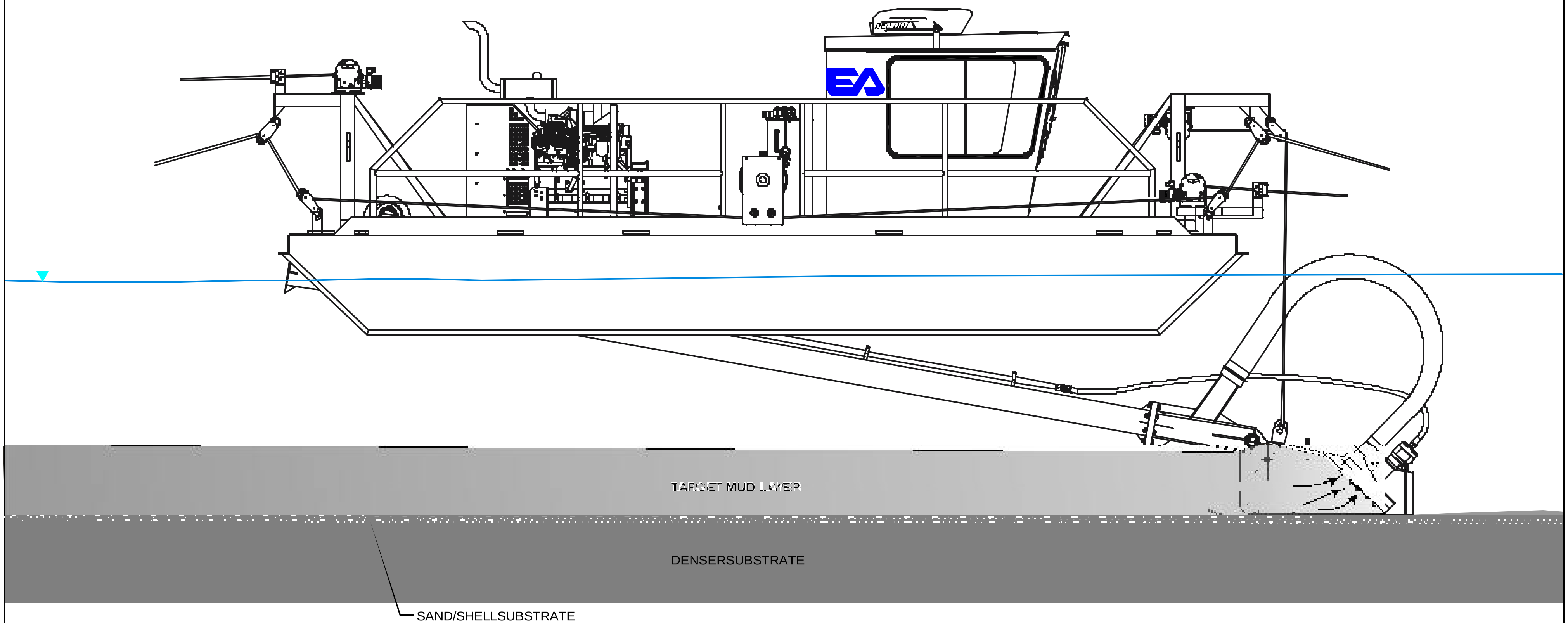

Figure 5-2 Cross-SectionalViewOfSEDCUTDredgeHeadAssembly

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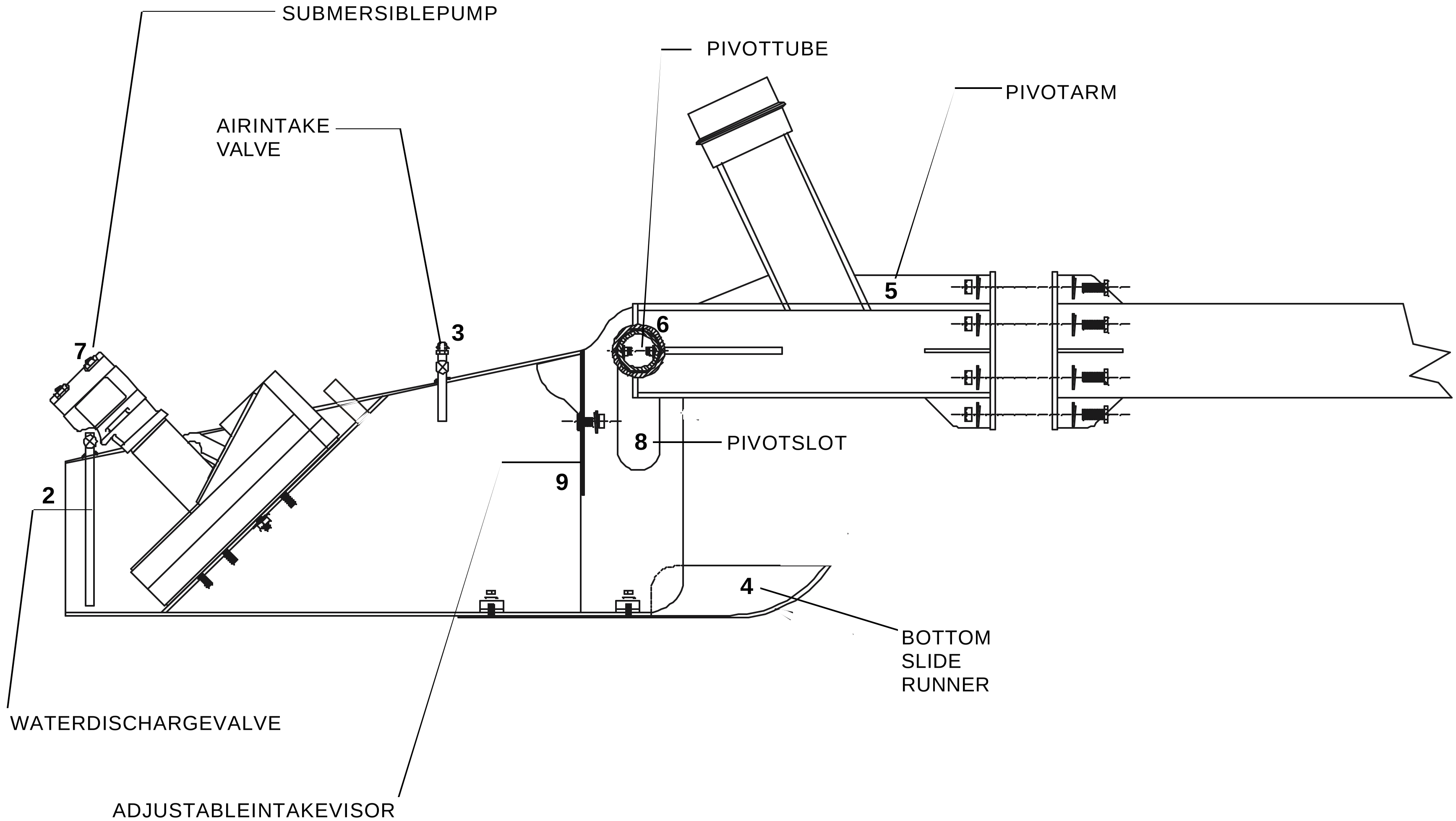

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Figure5-3 Cross-SectionalViewOfSEDCUTDredgeHead

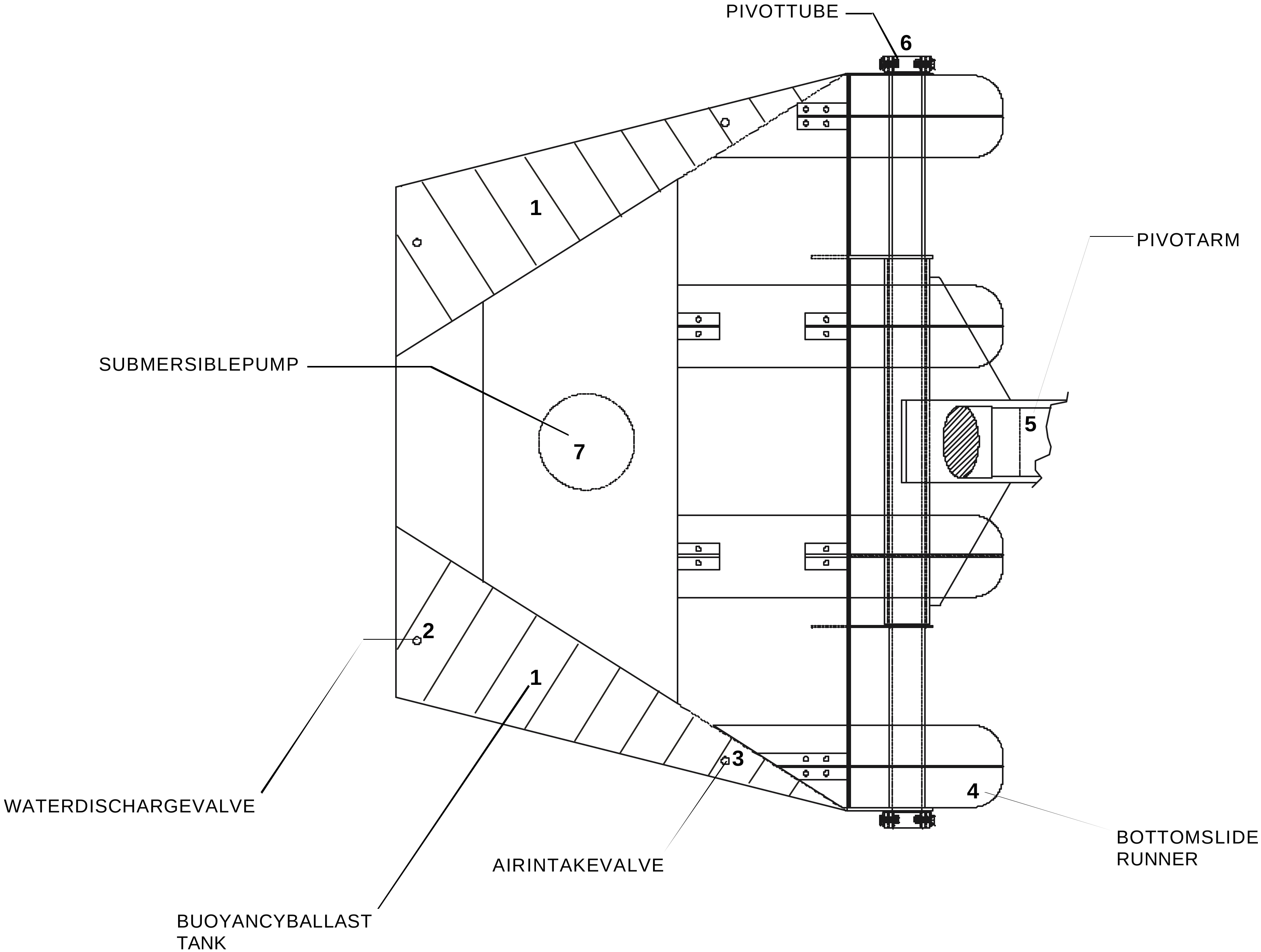

Figure5-4 PlanViewOfSEDCUTDredgeHead

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5.3 DREDGING METHODOLOGY & DATA COLLECTION

Field demonstration of the SEDCUT® technology was conducted in Lake Okeechobee during May 2002. A health & safety plan[1] was developed prior to start of field activities and all field activities were conducted in accordance with guidance and requirements of the project health & safety plan.

Pilot dredging was conducted in discrete lane cuts, which were approximately 200 ft [60.96 m] in length and 6 ft [1.8 m] in width. Adjustments to the dredge mouth opening height and travel speed were made for selected lanes. The following three variables were evaluated during the test:

1) **Horizontal Travel Speed –** The travel speed of the dredge unit was controlled by a winch system. The winch system was capable of moving the dredge unit between 5 ft/min [1.52 m/min] to 40 ft/min [12.19 m/min]. To evaluate the effects of the difference travel rates, the relative percentage of mud the dredge slurry was evaluated. Samples of the dredge slurry were collected in l liter sampling containers and allowed to settle for 24 hours. The relative percentage of mud was then measured and compared to the measured volume of water that visually separated from the dredge slurry within the container. The 24-hour period was selected as a representative time interval to allow for settling since visual observations during the bench-scale study had shown that most of the settling appeared to occur within the first 24 hours.

2) **Intake Visor:** The vertical height of the intake opening was adjusted during the test using an adjustable intake visor that was installed at the top of the mouth area. The visor was adjusted from 12 ft [30.5 cm] (100% of the mud layer thickness) to 2 ft [5 cm] (16% of the mud layer thickness), to evaluate the impact of shielding dilution water from entering the dredge head. Results of the various intake openings indicated that the 6 in [15 cm] opening generated the highest relative percentage of mud in the dredge slurry.

3) **Contact Pressure:** Ballast tanks were used to reduce the unit's contact pressure and allow it to slide on the denser substrate. For all runs, except the last one, the ballast tanks were held empty. The tanks were flooded prior to initiating the last run to evaluate the effects of

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[1] *Lake Okeechobee Pilot Dredging Project – Health & Safety Plan* (EA, 2001e).

increasing the unit's weight and thereby increasing the contact pressure. The additional weight of the flooded tanks allowed the unit to be lowered an additional 0.9 ft [0.27 m] deeper than the previous lane cut. No change in dredged sediments characteristics was observed due to increase in the unit's contact pressure.

Sediments removed during each lane cut were pumped directly into one of the eight compartments of the tank barge for temporary storage prior to transfer to the CDF, usually at the end of the operating day.

For each lane cut, grab samples of the dredge slurry were collected at the tank barge directly from the 6 in discharge line. Two to six grab samples were obtained per lane cut and stored in containers of known volume, usually 1 liter. Grab samples were analyzed in the field, to determine the relative percentage of mud collected versus dilution water during each lane cut, and to provide feedback on the dredge's performance. Field data indicated that the 6 in [15.24 cm] vertical mouth opening generated a dredge slurry with the highest relative volume percentage of mud versus dilution water. Geotechnical and physical data analysis were determined (Appendix B).

Grain size, organic content, bulk density and percent solid data were used to determine the effectiveness of the dredging operations in selectively removing the target layer, and volume ratios were used to determine dredge operating efficiency and production rates. A 24 hour settling time was adopted from the time of aggravated disturbance for measurements of the mud in the sample containers. This time increment was selected based on the time required for clear definition of the mud layer. A total of 57 lanes were cut under various width openings and travel speeds (Table 5.3). Geotechnical and physical data were determined (Appendix B).

The density determinations for the target material and dredge slurry were based on the mathematical relationship between the mass of the material (weight) occupying a known or measured volume. No specific ASTM designation addresses the specific use, but the mathematical relationship and methodology is employed in several ASTM Designations including D2937 (Density of Soil in Place by the Drive Sleeve Method), D4254 (Minimum Index Density & Unit Weight of Soils and Calculation of Relative Density), D4531 (Bulk Density of Peat and Peat Products), and D4564 (Density of Soil in Place by Sleeve Method).

Table 5-2 Tests and determinations performed by Intercounty Laboratory

Parameters	Test Procedures and Function
Grain Size	Quantitative determination of the distribution of particle sizes ASTM D 442 (Sieve and Hydrometer tests)
Organic Content	Percent of organics by weight present in the sediment portion of the dredge slurry, ASTM D 2974
Bulk Density	Saturated unit weight of the mud in g/cm^3
Percent Solids	Dry unit weight of the solids divided by the total sample weight
Volume ratios	Volume of mud separated from the dredge slurry after 24 hours of settling

ASTM D2974 provides guidance for determination of moisture content, ash content, and percent organic matter in soils. Moisture is determined by drying the sample at 106 deg C; moisture content is generally expressed as a percent of the oven dry mass or the as-received mass. Ash content of a soil sample is determined by igniting the oven-dried sample from the moisture content determination in a muffle furnace at 440 deg C; the ash content is typically reported as percentage of the mass of the oven-dried sample. Organic matter is determined by subtracting percent ash content from one hundred.

5.3.1 Transfer of Dredged Material to the CDF

A modified decommissioned Navy tank barge was utilized to transport the dredge material from the PDS to the CDF. The tank barge contains eight equal chambers capable of holding up to 40,000 gallons [161,417 L] each with a maximum draft of 8 ft [2.44 m]. Due to the shallow channel approach experienced throughout the pilot dredging project of 7 ft [2.13 m] in the Port Mayaca channel, it was decided to limit the tank barge loading and maximum draft. The shallow channel depths at the Port Mayaca Lock initially limited us to filling the tank barge to a draft of 6.5 ft [1.98 m] (approximately 55% of its capacity) before each transport cycle. However, it was later determined that, due either to seiching of the Lake from strong easterly winds or other factors, the tug was dragging the bottom in the channel approaching the Port Mayaca lock at a draft of slightly less than 7 ft [2.13 m]. On one occasion, it actually ran aground in the approach channel. To avoid further mishaps, for all subsequent trips the barge was loaded to allow for a maximum draft of less than 6 ft [1.83 m], approximately 40– 45% of the barge capacity.

Table 5-3 Pilot Dredging Project Operations Schedule Dredging Runs Characterization Data

Day	Date	Quadrant	Run	Sedcut Opening	Lane	Dredging Operations		Run Time (min)	Travel Length (ft)	Travel Length (m)	Travel Speed (fpm)	Travel Speed (m/s)	Cable Speed[Note 1] (fpm)	Cable Speed[Note 1] (m/s)	Pumping Rate (gpm)	Pumping Rate (l/s)
						Start	Stop									
Sunday	5/13/2002	SE	1	2-inch	400	3:05	3:25	20	210	64.01	10.50	0.053	0.3	0.0015	1350	85.17
Sunday	5/13/2002	SE	2	2-inch	400	3:35	3:48	13	136.5	41.61	10.50	0.053	0.3	0.0015	1350	85.17
Friday	5/17/2002	SE	1	2-inch	400	3:54	4:06	12	210	64.01	17.50	0.088	0.3	0.0015	1119	70.60
Friday	5/17/2002	SE	2	2-inch	394	4:30	4:45	15	210	64.01	14.00	0.070	0.3	0.0015	1089	68.71
Friday	5/17/2002	SE	3	2-inch	383	5:23	5:30	14	210	64.01	15.00	0.075	0.3	0.0015	1109	69.97
Monday	5/20/2002	NE	1	4-inch	400	3:09	3:23	14	200	60.96	14.20	0.071	0.3	0.0015	1123	70.85
Monday	5/20/2002	NE	2	4-inch	394	4:33	4:49	16	200	60.96	12.50	0.063	0.3	0.0015	1412	89.08
Monday	5/20/2002	NE	3	4-inch	383	5:22	5:38	16	200	60.96	12.50	0.063	0.2	0.001	1446	91.23
Monday	5/20/2002	NE	4	4-inch	377	6:54	7:08	14	200	60.96	14.20	0.071	0.3	0.0015	1123	70.85
Tuesday	5/21/2002	NE	1	4-inch	371	11:11	11:26	15	200	60.96	13.30	0.067	0.3	0.0015	1350	85.17
Tuesday	5/21/2002	NE	2	4-inch	366	11:45	11:58	13	200	60.96	15.38	0.077	0.3	0.0015	1350	85.17
Friday	5/24/2002	NE	1	6-inch	345	11:02	11:23	21	200	60.96	9.52	0.048	0.4	0.002	1411	89.02
Friday	5/24/2002	NE	2	6-inch	339	12:00	12:10	10	200	60.96	20.00	0.100	0.4	0.002	1411	89.02
Friday	5/24/2002	NE	3	6-inch	333	12:31	12:43	12	200	60.96	16.60	0.083	0.3	0.0015	1182	74.57
Friday	5/24/2002	NE	4	6-inch	327	12:54	13:06	12	200	60.96	16.60	0.083	0.3	0.0015	1182	74.57
Friday	5/24/2002	NE	5	6-inch	321	13:16	13:29	13	200	60.96	15.38	0.077	0.3	0.0015	1333	84.10
Friday	5/24/2002	NE	6	6-inch	315	13:40	13:50	10	200	60.96	20.00	0.100	0.3	0.0015	1333	84.10
Friday	5/24/2002	NE	7	6-inch	309	14:09	14:24	15	200	60.96	13.30	0.067	0.3	0.0015	1342	84.67
Friday	5/24/2002	NE	8	6-inch	303	14:34	14:42	8	200	60.96	25.00	0.125	0.3	0.0015	1342	84.67
Friday	5/24/2002	NE	9	6-inch	297	14:59	15:10	11	200	60.96	18.18	0.091	0.3	0.0015	1456	91.86
Saturday	5/25/2002	NE	1	8-inch	291	11:00	11:11	11	200	60.96	18.18	0.091	0.3	0.0015	1226	77.35
Saturday	5/25/2002	NE	2	8-inch	285	11:30	11:41	11	200	60.96	18.18	0.091	0.3	0.0015	1226	77.35
Saturday	5/25/2002	NE	3	8-inch	279	11:54	12:11	17	200	60.96	11.76	0.059	0.2	0.001	1156	72.93
Saturday	5/25/2002	NE	4	8-inch	273	12:23	12:57	34	200	60.96	5.88	0.029	0.1	0.0005	1325	83.59
Saturday	5/25/2002	NE	5	8-inch	267	13:16	13:23	7	200	60.96	28.57	0.143	0.4	0.002	1206	76.09
Saturday	5/25/2002	NE	6	8-inch	261	13:36	13:41	5	200	60.96	40.00	0.200	0.5	0.0025	1206	76.09
Saturday	5/25/2002	NE	7	8-inch	255	14:01	14:06	5	200	60.96	40.00	0.200	0.6	0.003	1230	77.60
Monday	5/27/2002	NE	1	6-inch	249	10:23	11:06	36	200	60.96	5.56	0.028	0.1	0.0005	1408	88.83
Monday	5/27/2002	NE	2	6-inch	243	11:25	11:42	17	200	60.96	11.76	0.059	0.2	0.001	1372	86.56
Monday	5/27/2002	NE	3	6-inch	237	11:55	12:08	13	200	60.96	15.38	0.077	0.2	0.001	1356	85.55
Monday	5/27/2002	NE	4	6-inch	231	12:20	12:30	10	200	60.96	20.00	0.100	0.4	0.002	1356	85.55
Monday	5/27/2002	NE	5	6-inch	225	12:43	12:50	7	200	60.96	28.57	0.143	0.5	0.0025	1356	85.55
Monday	5/27/2002	NE	6	6-inch	219	13:02	13:08	6	200	60.96	33.33	0.167	0.6	0.003	1206	76.09
Monday	5/27/2002	NE	7	6-inch	213	13:20	13:25	5	200	60.96	40.00	0.200	0.7	0.0035	1206	76.09
Tuesday	5/28/2002	NW	1	12-inch	194	10:31	10:37	6	200	60.96	33	0.165	0.5	0.0025	1294	81.64
Tuesday	5/28/2002	NW	2	12-inch	188	10:48	10:57	9	200	60.96	22	0.110	0.4	0.002	1294	81.64
Tuesday	5/28/2002	NW	3	12-inch	182	11:07	11:14	7	200	60.96	28.5	0.143	0.5	0.0025	1294	81.64
Tuesday	5/28/2002	NW	4	12-inch	176	11:25	11:30	5	200	60.96	40	0.200	0.6	0.003	1264	79.75
Tuesday	5/28/2002	NW	5	12-inch	170	11:43	11:48	5	200	60.96	40	0.200	0.7	0.0035	1264	79.75
Tuesday	5/28/2002	NW	6	12-inch	164	11:59	12:04	5	200	60.96	40	0.200	0.7	0.0035	1264	79.75
Tuesday	5/28/2002	NW	7	12-inch	158	12:17	12:23	6	200	60.96	33	0.165	0.6	0.003	1264	79.75
Tuesday	5/28/2002	NW	8	12-inch	152	12:41	12:48	7	200	60.96	28.5	0.143	0.5	0.0025	1332	84.04
Tuesday	5/28/2002	NW	9	12-inch	146	13:36	13:44	8	200	60.96	25	0.125	0.3	0.0015	1332	84.04
Tuesday	5/28/2002	NW	10	12-inch	140	14:11	14:22	11	200	60.96	18	0.090	0.3	0.0015	1332	84.04
Tuesday	5/28/2002	NW	11	12-inch	134	14:34	14:43	10	200	60.96	22	0.110	0.4	0.002	1351	85.23
Tuesday	5/28/2002	NW	12	12-inch	128	14:57	15:09	13	200	60.96	16.5	0.083	0.2	0.001	1351	85.23
Wednesday	5/29/2002	NW	1	10-inch	122	11:01	11:06	5	200	60.96	40	0.200	0.7	0.0035	1345	84.86
Wednesday	5/29/2002	NW	2	10-inch	116	11:18	11:24	6	200	60.96	33	0.165	0.5	0.0025	1345	84.86
Wednesday	5/29/2002	NW	3	10-inch	110	11:34	11:42	8	200	60.96	25	0.125	0.3	0.0015	1345	84.86
Wednesday	5/29/2002	NW	4	10-inch	104	11:54	12:02	9	200	60.96	25	0.125	0.3	0.0015	1416	89.34
Wednesday	5/29/2002	NW	5	10-inch	98	12:18	12:26	8	200	60.96	25	0.125	0.3	0.0015	1416	89.34
Wednesday	5/29/2002	NW	6	10-inch	92	12:39	12:46	7	200	60.96	28.5	0.143	0.5	0.0025	1500	94.64
Wednesday	5/29/2002	NW	7	10-inch	86	12:59	13:03	4	200	60.96	50	0.250	0.8	0.004	1500	94.64
Wednesday	5/29/2002	NW	8	10-inch	80	13:14	13:19	5	200	60.96	40	0.200	0.7	0.0035	1424	89.84
Wednesday	5/29/2002	NW	9	10-inch	74	13:32	13:39	7	200	60.96	28.5	0.143	0.5	0.0025	1319	83.22
Wednesday	5/29/2002	NW	10	10-inch	68	14:31	14:37	6	200	60.96	33	0.165	0.5	0.0025	1319	83.22

Note 1: Although reported in fpm and m/s, the Cable Speed was not calibrated to the Travel Speed.

Table 5-3 Pilot Dredging Project Operations Schedule Dredging Runs Characterization Data

Day	Date	Quadrant	Run	Sample % mud by vol. (based on field Meas)	Total Vol. (gal)	Total Vol. (liters)	Tanker No.	Total Vol. per load (gal)	Total Vol. per load (liters)	Fluid Mud Volume (ft^3)	Fluid Mud Volume (m^3)	Fluid Mud (lbs)	Fluid Mud (kg)	Amt. of P Removed (lbs)	Amt. of P Removed (kg)	Rate of P Rem. (lb/min)
Sunday	5/13/2002	SE	1	10	27,000	102,206	1			360.96	10.22	27028.88	12260.30	124.33	56.40	6.22
Sunday	5/13/2002	SE	2	10	17,550	66,434	1			234.63	6.64	17568.77	7969.19	80.82	36.66	6.22
Friday	5/17/2002	SE	1	42	13,428	50,830	1			753.98	21.35	56457.92	25609.31	259.71	117.80	21.64
Friday	5/17/2002	SE	2	22	16,335	61,835	1			480.44	13.60	35975.44	16318.46	165.49	75.06	11.03
Friday	5/17/2002	SE	3	18	15,526	58,772	1	89,839	340,077	373.62	10.58	27976.69	12690.23	128.69	58.38	9.19
Monday	5/20/2002	NE	1	22	15,722	59,514	2			462.41	13.09	34625.39	15706.08	159.28	72.25	11.38
Monday	5/20/2002	NE	2	17	22,592	85,520	2			513.45	14.54	38447.48	17439.78	176.86	80.22	11.05
Monday	5/20/2002	NE	3	20.5	23,136	87,579	2			634.07	17.96	47479.53	21536.71	218.41	99.07	13.65
Monday	5/20/2002	NE	4	28.5	15,722	59,514	2			599.03	16.96	44855.62	20346.51	206.34	93.59	14.74
Tuesday	5/21/2002	NE	1	14	20,250	76,654	2			379.01	10.73	28380.32	12873.31	130.55	59.22	8.70
Tuesday	5/21/2002	NE	2	14	17,550	66,434	2	130,498	493,987	328.48	9.30	24596.28	11156.87	113.14	51.32	8.70
Friday	5/24/2002	NE	1	45	29,631	112,165	3			1782.61	50.48	133482.11	60547.48	614.02	278.52	29.24
Friday	5/24/2002	NE	2	34	14,110	53,412	3			641.36	18.16	48025.31	21784.28	220.92	100.21	22.09
Friday	5/24/2002	NE	3	49	14,184	53,692	3			929.17	26.31	69575.93	31559.64	320.05	145.17	26.67
Friday	5/24/2002	NE	4	23	14,184	53,692	3			436.14	12.35	32658.09	14813.71	150.23	68.14	12.52
Friday	5/24/2002	NE	5	30	17,329	65,597	3			695.01	19.68	52042.60	23606.52	239.40	108.59	18.42
Friday	5/24/2002	NE	6	36	13,330	50,459	3			641.55	18.17	48039.32	21790.64	220.98	100.24	22.10
Friday	5/24/2002	NE	7	35	20,130	76,200	3			941.91	26.67	70530.35	31992.57	324.44	147.17	21.63
Friday	5/24/2002	NE	8	40	10,736	40,640	3			574.12	16.26	42989.93	19500.23	197.75	89.70	24.72
Friday	5/24/2002	NE	9	32	16,016	60,627	3	149,650	566,485	685.18	19.40	51306.01	23272.41	236.01	107.05	21.46
Saturday	5/25/2002	NE	1	24	13,486	51,050	4			438.11	12.41	32806.03	14880.81	150.91	68.45	13.72
Saturday	5/25/2002	NE	2	15	13,486	51,050	4			261.43	7.40	19575.61	8879.50	90.05	40.85	8.19
Saturday	5/25/2002	NE	3	24	19,652	74,391	4			618.99	17.53	46349.63	21024.19	213.21	96.71	12.54
Saturday	5/25/2002	NE	4	21	45,050	170,532	4			1234.66	34.96	92451.27	41935.90	425.28	192.91	12.51
Saturday	5/25/2002	NE	5	55	8,442	31,956	4			615.09	17.42	46058.11	20891.96	211.87	96.10	30.27
Saturday	5/25/2002	NE	6	45	6,030	22,826	4			362.77	10.27	27164.02	12321.60	124.95	56.68	24.99
Saturday	5/25/2002	NE	7	30	6,150	23,280	4	112,296	425,085	244.19	6.91	18285.04	8294.09	84.11	38.15	16.82
Monday	5/27/2002	NE	1	16	50,688	191,874	5			1084.24	30.70	81187.54	36826.67	373.46	169.40	10.37
Monday	5/27/2002	NE	2	37	23,324	88,291	5			1153.73	32.67	86391.10	39187.00	397.40	180.26	23.38
Monday	5/27/2002	NE	3	22	17,628	66,729	5			518.47	14.68	38823.08	17610.15	178.59	81.01	13.74
Monday	5/27/2002	NE	4	48	13,560	51,330	5			870.16	24.64	65157.61	29555.49	299.73	135.96	29.97
Monday	5/27/2002	NE	5	57	9,492	35,931	5			723.32	20.48	54162.27	24568.00	249.15	113.01	35.59
Monday	5/27/2002	NE	6	52	7,236	27,391	5			503.04	14.24	37667.44	17085.95	173.27	78.60	28.88
Monday	5/27/2002	NE	7	66	6,030	22,826	5	77,270	292,498	532.06	15.07	39840.56	18071.68	183.27	83.13	36.65
Tuesday	5/28/2002	NW	1	48	7,764	29,390	6			498.22	14.11	37307.06	16922.48	171.61	77.84	28.60
Tuesday	5/28/2002	NW	2	16	11,646	44,085	6			249.11	7.05	18653.53	8461.24	85.81	38.92	9.53
Tuesday	5/28/2002	NW	3	47	9,058	34,288	6			569.15	16.12	42618.13	19331.58	196.04	88.93	28.01
Tuesday	5/28/2002	NW	4	38	6,320	23,924	6			321.07	9.09	24041.69	10905.31	110.59	50.16	22.12
Tuesday	5/28/2002	NW	5	36	6,320	23,924	6			304.17	8.61	22776.33	10331.34	104.77	47.52	20.95
Tuesday	5/28/2002	NW	6	37	6,320	23,924	6			312.62	8.85	23409.01	10618.33	107.68	48.84	21.54
Tuesday	5/28/2002	NW	7	56	7,584	28,708	6			567.79	16.08	42515.82	19285.18	195.57	88.71	32.60
Tuesday	5/28/2002	NW	8	34	9,324	35,295	6			423.82	12.00	31735.51	14395.23	145.98	66.22	20.85
Tuesday	5/28/2002	NW	9	35	10,656	40,337	6			498.61	14.12	37335.89	16935.56	171.75	77.90	21.47
Tuesday	5/28/2002	NW	10	31	14,652	55,464	6			607.24	17.20	45469.78	20625.09	209.16	94.88	19.01
Tuesday	5/28/2002	NW	11	34	13,510	51,141	6			614.09	17.39	45983.13	20857.95	211.52	95.95	21.15
Tuesday	5/28/2002	NW	12	12	17,563	66,483	6	120,717	456,962	281.76	7.98	21098.14	9570.12	97.05	44.02	7.47
Wednesday	5/29/2002	NW	1	48	6,725	25,457	7			431.55	12.22	32314.52	14657.87	148.65	67.43	29.73
Wednesday	5/29/2002	NW	2	28	8,070	30,548	7			302.09	8.55	22620.17	10260.51	104.05	47.20	17.34
Wednesday	5/29/2002	NW	3	35	10,760	40,731	7			503.48	14.26	37700.28	17100.85	173.42	78.66	21.68
Wednesday	5/29/2002	NW	4	39	12,744	48,241	7			664.46	18.82	49754.76	22568.76	228.87	103.82	25.43
Wednesday	5/29/2002	NW	5	42	11,328	42,881	7			636.06	18.01	47628.49	21604.28	219.09	99.38	27.39
Wednesday	5/29/2002	NW	6	55	10,500	39,747	7			772.06	21.86	57811.76	26223.42	265.93	120.63	37.99
Wednesday	5/29/2002	NW	7	32	6,000	22,712	7			256.68	7.27	19220.53	8718.43	88.41	40.10	22.10
Wednesday	5/29/2002	NW	8	40	7,120	26,952	7			380.75	10.78	28510.46	12932.34	131.15	59.49	26.23
Wednesday	5/29/2002	NW	9	33	9,233	34,951	7			407.34	11.53	30501.49	13835.47	140.31	63.64	20.04
Wednesday	5/29/2002	NW	10	20	7,914	29,958	7	90,394	342,177	211.60	5.99	15844.93	7187.26	72.89	33.06	12.15
								680,825	2,577,195	31421.11	889.75	2251757.12	1021397.03	10358.08	4698.43	

Note 1: Although reported in fpm and m/s, the Cable Speed was not calibrated to the Travel Speed.

Table 5-3 Pilot Dredging Project Operations Schedule Dredging Runs Characterization Data

Day	Date	Quadrant	Run	Rate of P Rem. (kg/s)	Avg. % Saturated Sed. by volume	Avg. Bulk Density (g/cm^3)	Avg. % Solids per sample	Cable Depth (ft)	Cable Depth (m)	Depth Dredge Unit Lowered (ft)	Depth Dredge Unit Lowered (m)
Sunday	5/13/2002	SE	1	0.05				11.20	3.41		
Sunday	5/13/2002	SE	2	0.05				12.10	3.69		
Friday	5/17/2002	SE	1	0.16				13.70	4.18		
Friday	5/17/2002	SE	2	0.08					0.00		
Friday	5/17/2002	SE	3	0.07					0.00		
Monday	5/20/2002	NE	1	0.09					0.00		
Monday	5/20/2002	NE	2	0.08					0.00		
Monday	5/20/2002	NE	3	0.10					0.00		
Monday	5/20/2002	NE	4	0.11				14	4.27		
Tuesday	5/21/2002	NE	1	0.07					0.00		
Tuesday	5/21/2002	NE	2	0.07					0.00		
Friday	5/24/2002	NE	1	0.22					0.00	13	4.0
Friday	5/24/2002	NE	2	0.17					0.00		0.0
Friday	5/24/2002	NE	3	0.20					0.00	14	4.3
Friday	5/24/2002	NE	4	0.09					0.00	13.1	4.0
Friday	5/24/2002	NE	5	0.14				14	4.27	13.1	4.0
Friday	5/24/2002	NE	6	0.17				14.00	4.27	13.1	4.0
Friday	5/24/2002	NE	7	0.16				13.50	4.11	14	4.3
Friday	5/24/2002	NE	8	0.19				13.10	3.99	13.1	4.0
Friday	5/24/2002	NE	9	0.16				13.50	4.11	14	4.3
Saturday	5/25/2002	NE	1	0.10					0.00	13.1	4.0
Saturday	5/25/2002	NE	2	0.06					0.00	13.7	4.2
Saturday	5/25/2002	NE	3	0.09					0.00	13.5	4.1
Saturday	5/25/2002	NE	4	0.09					0.00	14	4.3
Saturday	5/25/2002	NE	5	0.23					0.00	13.1	4.0
Saturday	5/25/2002	NE	6	0.19				13.10	3.99	13.5	4.1
Saturday	5/25/2002	NE	7	0.13				13.1	3.99	14	4.3
Monday	5/27/2002	NE	1	0.08	16.90	1.36			0.00	13.7	4.2
Monday	5/27/2002	NE	2	0.18	34.95	1.23	12.13	14.00	4.27	14	4.3
Monday	5/27/2002	NE	3	0.10	20.83	1.32		13.1	3.99	14.5	4.4
Monday	5/27/2002	NE	4	0.23	45.63	1.18	12.78		0.00	13.1	4.0
Monday	5/27/2002	NE	5	0.27	53.53	1.17	14.78		0.00	13.1	4.0
Monday	5/27/2002	NE	6	0.22	48.25	1.19	13.15		0.00	14	4.3
Monday	5/27/2002	NE	7	0.28	60.58	1.15	14.35	12.10	3.69	13.1	4.0
Tuesday	5/28/2002	NW	1	0.22					0.00	14	4.3
Tuesday	5/28/2002	NW	2	0.07					0.00	14	4.3
Tuesday	5/28/2002	NW	3	0.21					0.00	14.2	4.3
Tuesday	5/28/2002	NW	4	0.17				14.00	4.27	14.7	4.5
Tuesday	5/28/2002	NW	5	0.16				14.00	4.27	13.5	4.1
Tuesday	5/28/2002	NW	6	0.16				14.00	4.27	14	4.3
Tuesday	5/28/2002	NW	7	0.25					0.00	13.2	4.0
Tuesday	5/28/2002	NW	8	0.16					0.00	14	4.3
Tuesday	5/28/2002	NW	9	0.16				13.10	3.99	14.1	4.3
Tuesday	5/28/2002	NW	10	0.14				14	4.27	14.1	4.3
Tuesday	5/28/2002	NW	11	0.16				13.10	3.99	14	4.3
Tuesday	5/28/2002	NW	12	0.06					0.00	14.2	4.3
Wednesday	5/29/2002	NW	1	0.22					0.00	13.1	4.0
Wednesday	5/29/2002	NW	2	0.13				13.1	3.99	14	4.3
Wednesday	5/29/2002	NW	3	0.16				13.10	3.99	13.1	4.0
Wednesday	5/29/2002	NW	4	0.19				13.00	3.96	13.5	4.1
Wednesday	5/29/2002	NW	5	0.21					0.00	13.1	4.0
Wednesday	5/29/2002	NW	6	0.29					0.00	13.7	4.2
Wednesday	5/29/2002	NW	7	0.17				13.10	3.99	13.5	4.1
Wednesday	5/29/2002	NW	8	0.20				13.00	3.96		
Wednesday	5/29/2002	NW	9	0.15				13.7	4.18		
Wednesday	5/29/2002	NW	10	0.09					0.00		

Note 1: Although reported in fpm and m/s, the Cable Speed was not calibrated to the Travel Speed.

The initial plans called for a crane barge at the CDF to support the unloading operation. However, it was concluded that, due to the high winds and seas, the crane barge was needed at the PDS to support reconfiguration of the dredge equipment due to shifts in wind direction and safe bed-down of the equipment at night. A truck-mounted boom with a 90 ft [27.43 m] reach was procured to replace the crane barge at the CDF site during barge unloading operations. The boom was used to position the transfer line and pump for the transfer of the dredged sediment from the tank barge to the holding cells at the CDF.

5.4 EVALUATION OF DREDGING DATA

Results indicate that SEDCUT® technology was very successful in achieving the goals of the project. Using a 6 in [15 cm] mouth opening and travel rate of 40 ft/min [12.9 m/min], the SEDCUT® dredge head successfully removed a dredge slurry containing up to 65% target mud and 35% dilution water, which translates into 93% removal efficiency when compared to the predicted (theoretical) production rate (Table 5-4 and Figure 5-5). Comparison of predicted versus actual production rates for the 8 in [20.32 cm], 10 in [25.4 cm], and 12 in [30 cm] mouth openings are shown in Tables 5-5, 5-6, and 5-7, respectively and graphically presented in Figures 5-6, 5-7, and 5-8.

The success of dredging (i.e. accurately removing the target mud layer) was determined by comparing the bulk density and gain size distribution properties of the dredge slurry to the target material. Results indicate that the unit performed most effectively at a 6 in [15.24 cm] mouth opening and a travel rate of 40 ft/min [12.19 m/min]; comparison of physical properties of the dredge slurry with the in-situ target material for this specific combination are shown in Table 5-8. It was also observed that the profile of the dredged material closely matches the profile of the mud layer with the exception of the bulk density of the extremely low travel rates (Figure 5-9). The efficiency and production rates of the dredging operations were determined by the relative ratio of mud versus dilution water in the dredge slurry.

Travel Speed – Comparison of different travel rates indicated that the faster travel rates generated a higher relative percentage of mud in the dredge slurry than water. Since the winch system could not travel faster than 40 ft/min [12.19 m/min], it is unknown if a faster travel rate would have generated a higher relative percentage of mud in the dredge slurry.

Intake Visor – The opening of the inlet visor was varied during the pilot project to evaluate the effectiveness of different intake (mouth) vertical openings. The mouth opening height of the unit was varied from 2 in (5 cm) to 12 in [30.48 cm] (100% of the target material thickness). Results of the various runs showed that a 6 in [15 cm] mouth opening (50% of the target material thickness) generated a slurry with the highest percentage of mud by volume. The travel rate was also varied for the different mouth openings. Similar trends were observed in all runs that revealed that the percentage of target material in the dredge slurry increased with higher travel rates. The most effective run for the 6 in [15 cm] mouth opening was determined to be 40 ft/min [12.19 m/min] (Figure 5-10). Volume measurements from this lane cut showed that the dredge slurry contained a relative ratio of 65% mud and 35 % dilution water.

Contact Pressure – Comparisons of mud volumes to inlet visor opening heights, travel time, and contact pressure indicated that the optimum dredge conditions were at 40 ft/min [12.19 m/min] with a 6 in [15 cm] opening (Figure 5-6). The pumping rate of 1,300 gpm (4,921 l/min) was constant throughout the test and was only shown to have slight variations (1–2 %). These minor variations in the pumping rates were attributed to varying head losses associated with the various pipe configurations utilized for each lane.

Table 5-4 Comparison of Predicted vs Actual Mud Production Rates for the 6-inch mouth opening

Dredge Production Rate:	1,300 gpm
	173.8 ft3/min
Dredge Surface Area (6 ft * .5ft intake):	3 ft2
Travel Rate to required to remove 100% volume (173.8 ft3/min/3ft):	58 ft/min
	29 ft/min

Predicted		Actual			Difference Range	
% Volume of mud in dredge slurry	Travel Rate (fpm)	% Volume of mud in dredge slury Low	% Volume of mud in dredge slury High	Travel Rate (fpm)	Low	High
100%	58					
90%	52					
85%	49					
80%	46					
75%	43					
70%	41	55%	65%	40	79%	93%
65%	38					
60%	35	35%	61%	33	58%	102%
55%	32					
50%	29	51%	60%	28	102%	120%
45%	26					
40%	23					
35%	20	41%	54%	20	117%	154%
30%	17					
25%	14	17%	24%	15	68%	96%
20%	12	32%	39%	11	160%	195%
15%	9					
10%	6	12%	25%	5.5	118%	250%
5%	3					

Figure 5-5 Dredge Production Efficiency For 6-Inch Intake Opening (Based on Field Calculations)

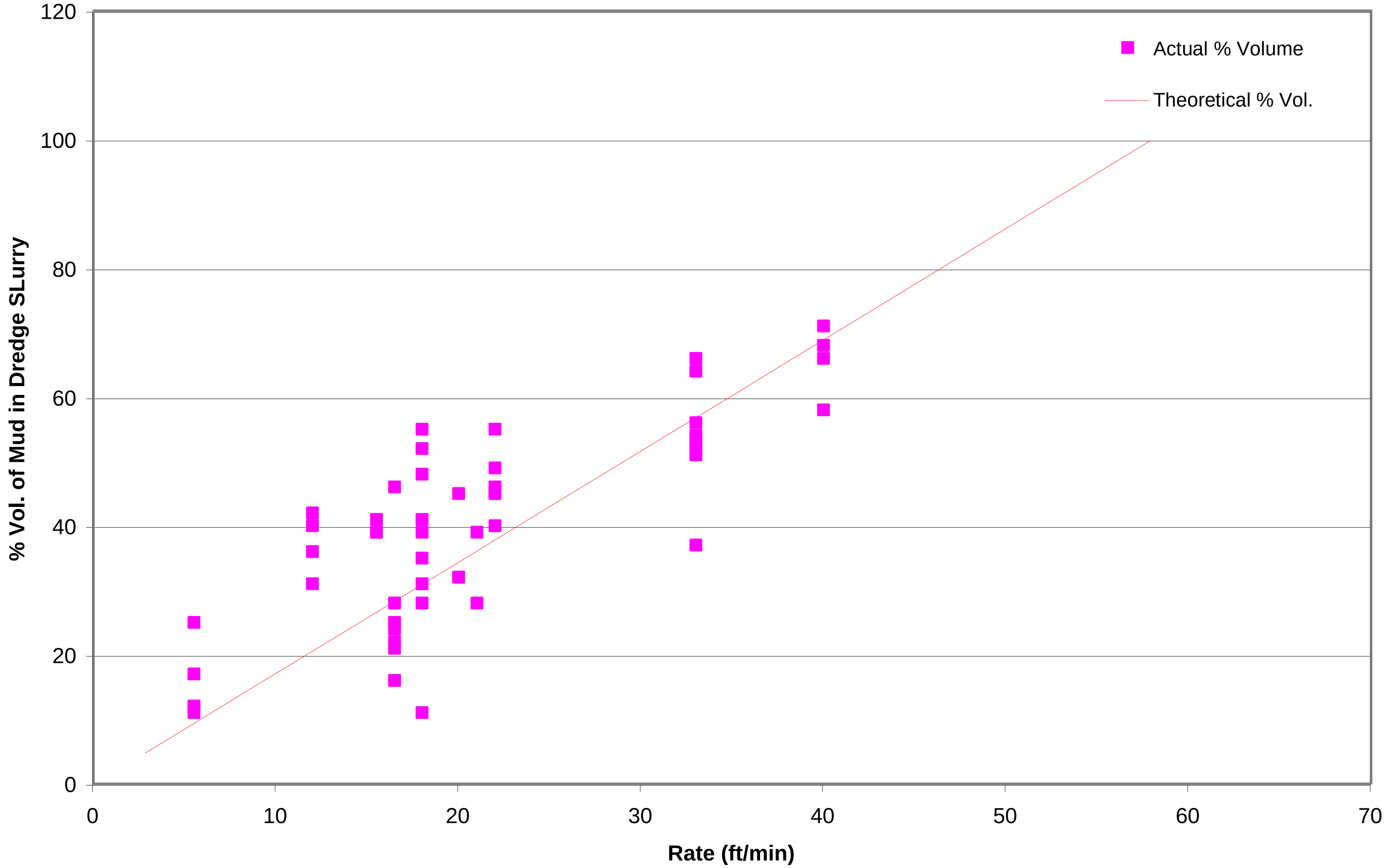


Table 5-5 Comparison of Predicted vs Actual Mud Production Rates for the 8-inch mouth opening

Dredge Production Rate:	1,300 gpm
	173.8 ft3/min
Dredge Surface Area (6 ft * .66ft intake):	3.96 ft2
Travel Rate to required to remove 100% volume (173.8 ft3/min/3.96ft):	44 ft/min
	29 ft/min

Predicted		Actual			Difference Range	
% Volume of mud in dredge slurry	Travel Rate (fpm)	% Volume of mud in dredge slury		Travel Rate (fpm)		
		Low	High		Low	High
100%	44.0					
90%	39.6	20%	43%	40	22%	1%
85%	37.4					
80%	35.2					
75%	33.0	35%	55%	33	47%	2%
70%	30.8					
65%	28.6	48%	61%	28.5	74%	2%
60%	26.4					
55%	24.2					
50%	22.0	12%	35%	22	24%	2%
45%	19.8	9%	20%	20	20%	1%
40%	17.6					
35%	15.4					
30%	13.2	23%	24%	14	77%	2%
25%	11.0					
20%	8.8					
15%	6.6	9%	36%	6.5	60%	5%
10%	4.4					
5%	2.2					

Figure 5-6 Dredge Production Efficiency For 8-Inch Intake Opening (Based on Field Calculations)

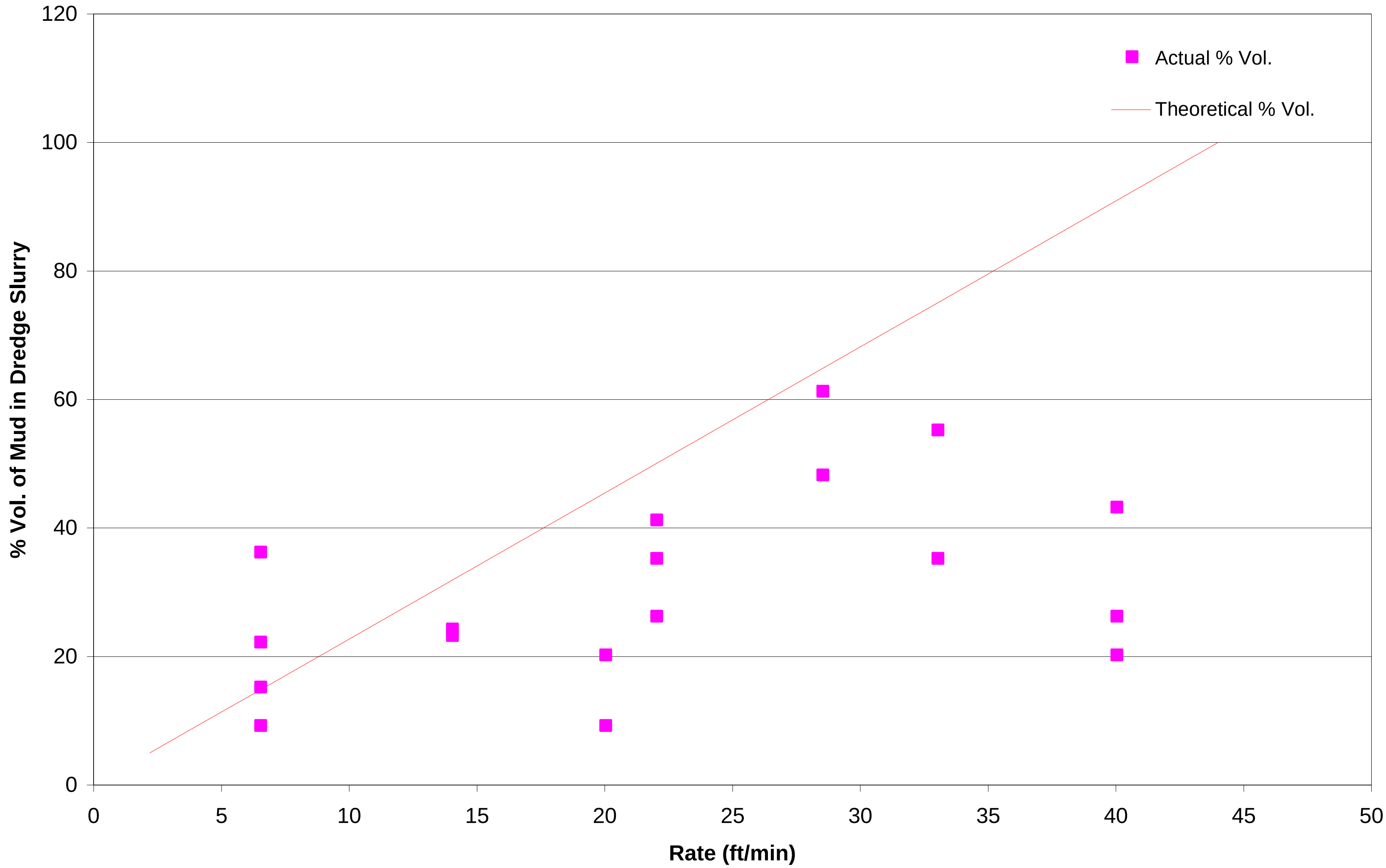


Table 5-6 Comparison of Predicted vs Actual Mud Production Rates for the 10-inch mouth opening

Dredge Production Rate:	1,300 gpm
	173.8 ft3/min
Dredge Surface Area (6 ft * .83ft intake):	4.98 ft2
Travel Rate to required to remove 100% volume (173.8 ft3/min/4.98ft):	35 ft/min
	29 ft/min

Predicted		Actual				
% Volume of mud in dredge slurry	Travel Rate (fpm)	% Volume of mud in dredge slury		Travel Rate (fpm)	Difference Range	
		Low	High		Low	High
		27%	65%	50		
		25%	61%	40		
100%	34.9	20%	41%	33	20%	1%
90%	31.4					
85%	29.7					
80%	27.9	29%	62%	28.5	36%	2%
75%	26.2					
70%	24.4	33%	53%	25	47%	2%
65%	22.7					
60%	20.9					
55%	19.2					
50%	17.5					
45%	15.7					
40%	14.0					
35%	12.2					
30%	10.5					
25%	8.7					
20%	7.0					
15%	5.2					
10%	3.5					
5%	1.7					

Figure 5-7 Dredge Production Efficiency For 10-inch Intake Opening (Based on field calculations)

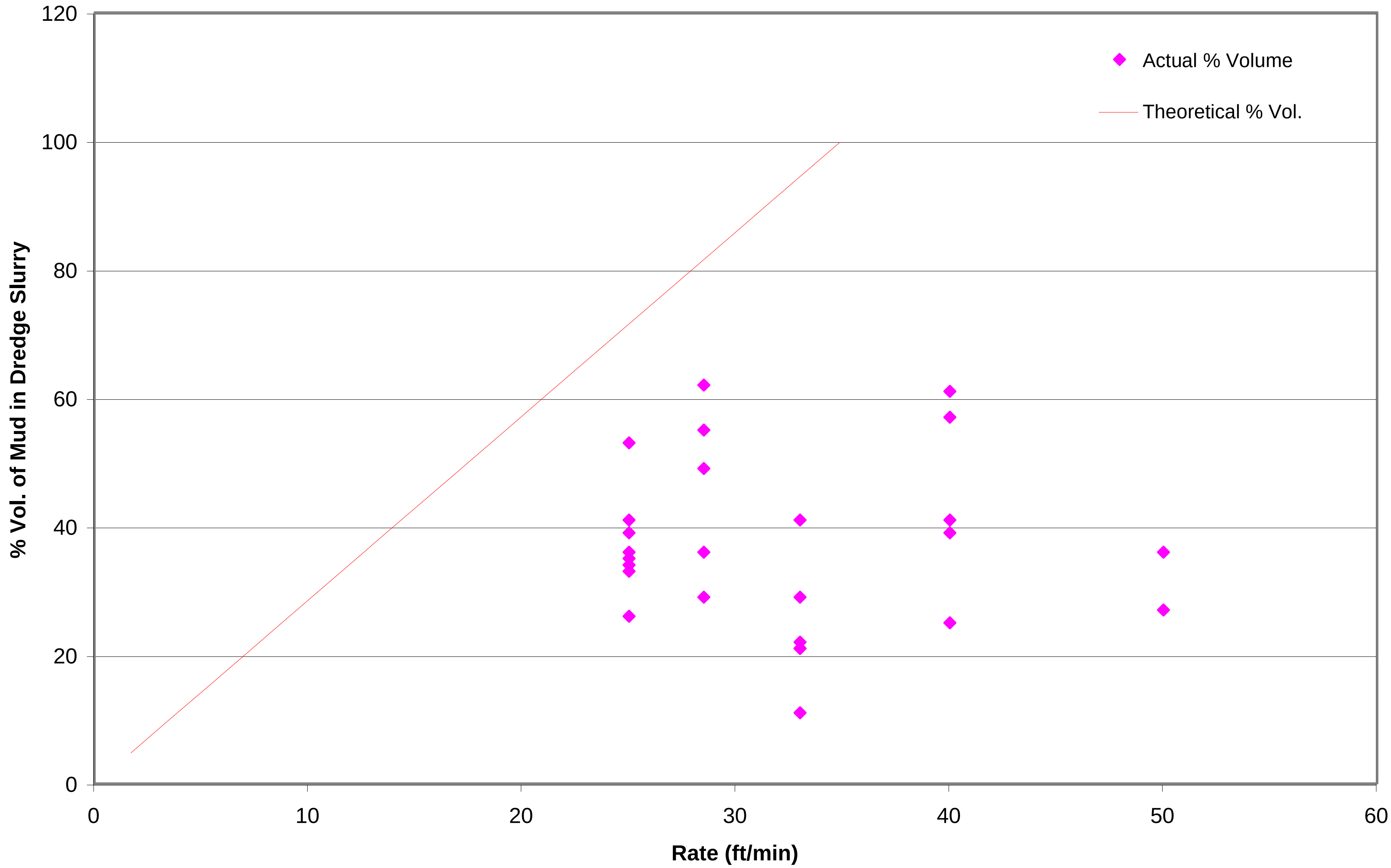


Table 5-7 Comparison of Predicted vs Actual Mud Production Rates for the 12-inch mouth opening

Dredge Production Rate:	1,300 gpm
	173.8 ft3/min
Dredge Surface Area (6 ft * 1ft intake):	6 ft2
Travel Rate to required to remove 100% volume (173.8 ft3/min/6ft):	29 ft/min

Predicted		Actual			Difference Range	
% Volume of mud in dredge slurry	Travel Rate (fpm)	% Volume of mud in dredge slury		Travel Rate (fpm)		
		Low	High		Low	High
		18%	55%	40		
		32%	67%	33		
100%	29.0	19%	52%	28.5	19%	2%
90%	26.1					
85%	24.7	31%	41%	25	36%	2%
80%	23.2					
75%	21.8	5%	39%	22	7%	2%
70%	20.3					
65%	18.9					
60%	17.4	29%	34%	18	48%	2%
55%	16.0	8%	16%	16.5	15%	1%
50%	14.5					
45%	13.1					
40%	11.6					
35%	10.2					
30%	8.7					
25%	7.3					
20%	5.8					
15%	4.4					
10%	2.9					
5%	1.5					

Figure 5-8 Dredge Production Efficiency For 12-inch Intake Opening (Based on field calculations)

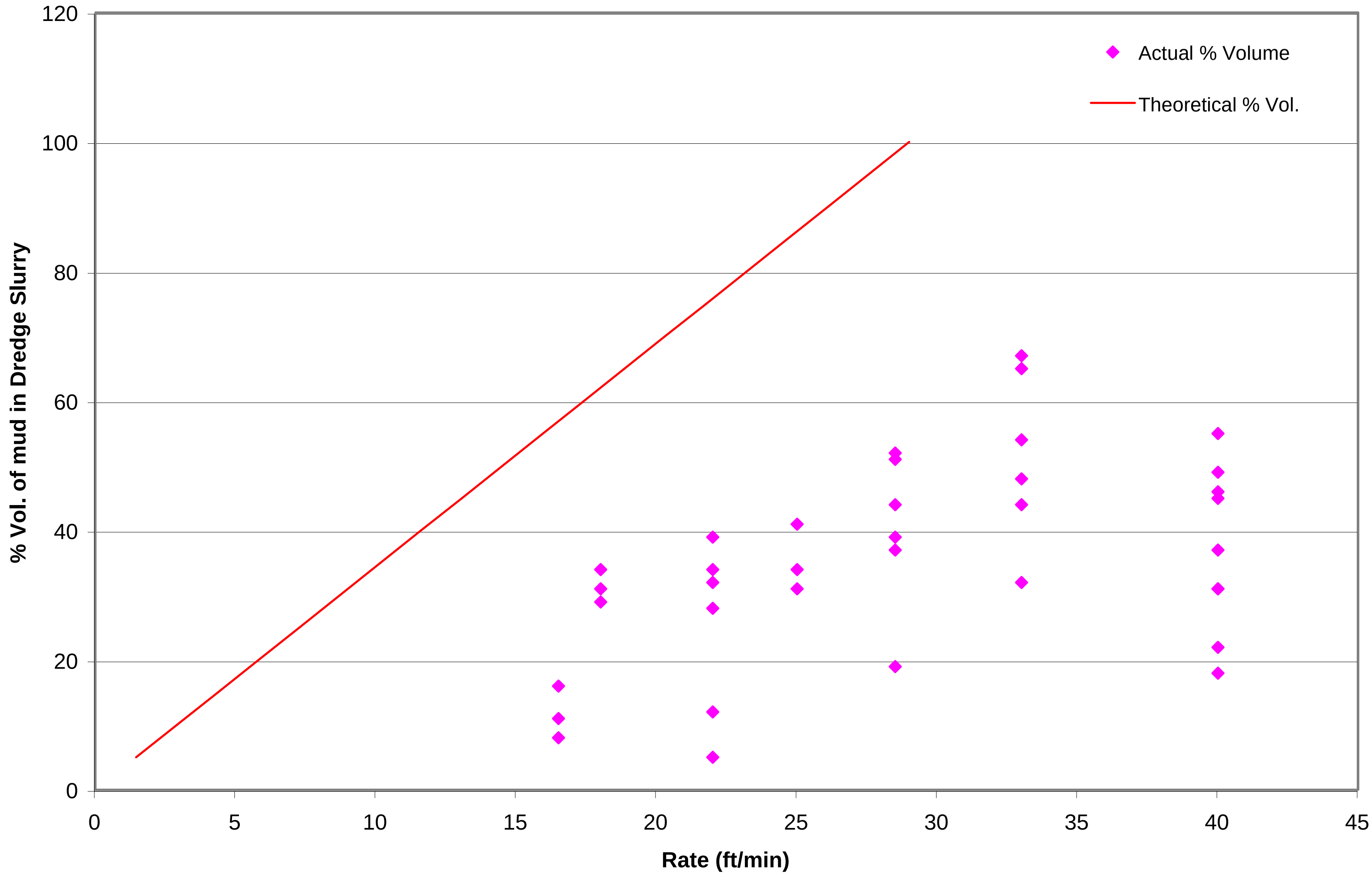


Table 5-8 Comparison Of Physical Properties Of The Dredge Slurry With In-Situ Target Material

Physical Parameter	Dredge Slurry	In-situ Target Material
Percent Water (by weight)	86.56	78.94
Percent Solids (by weight)	13.44	21.06
Bulk Density (g/cm^3)	1.24	1.20
Percent Organic (by weight)	28.5	37.4
Grain size (% minus No. 200)	70.4	77.3

Figure 5-9 Bulk Density Distribution 6-inch Vertical Mouth Height Opening vs Travel Rate

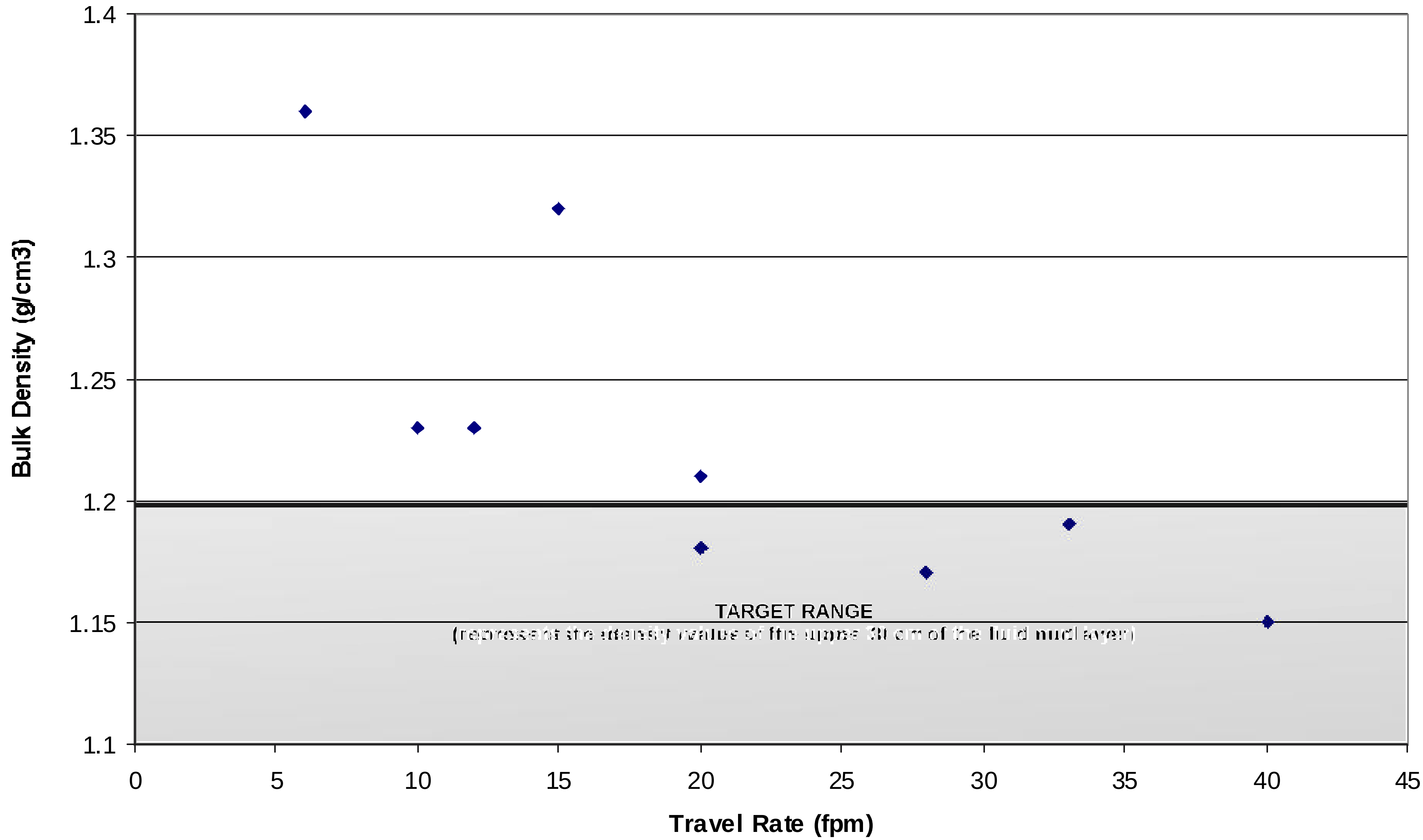
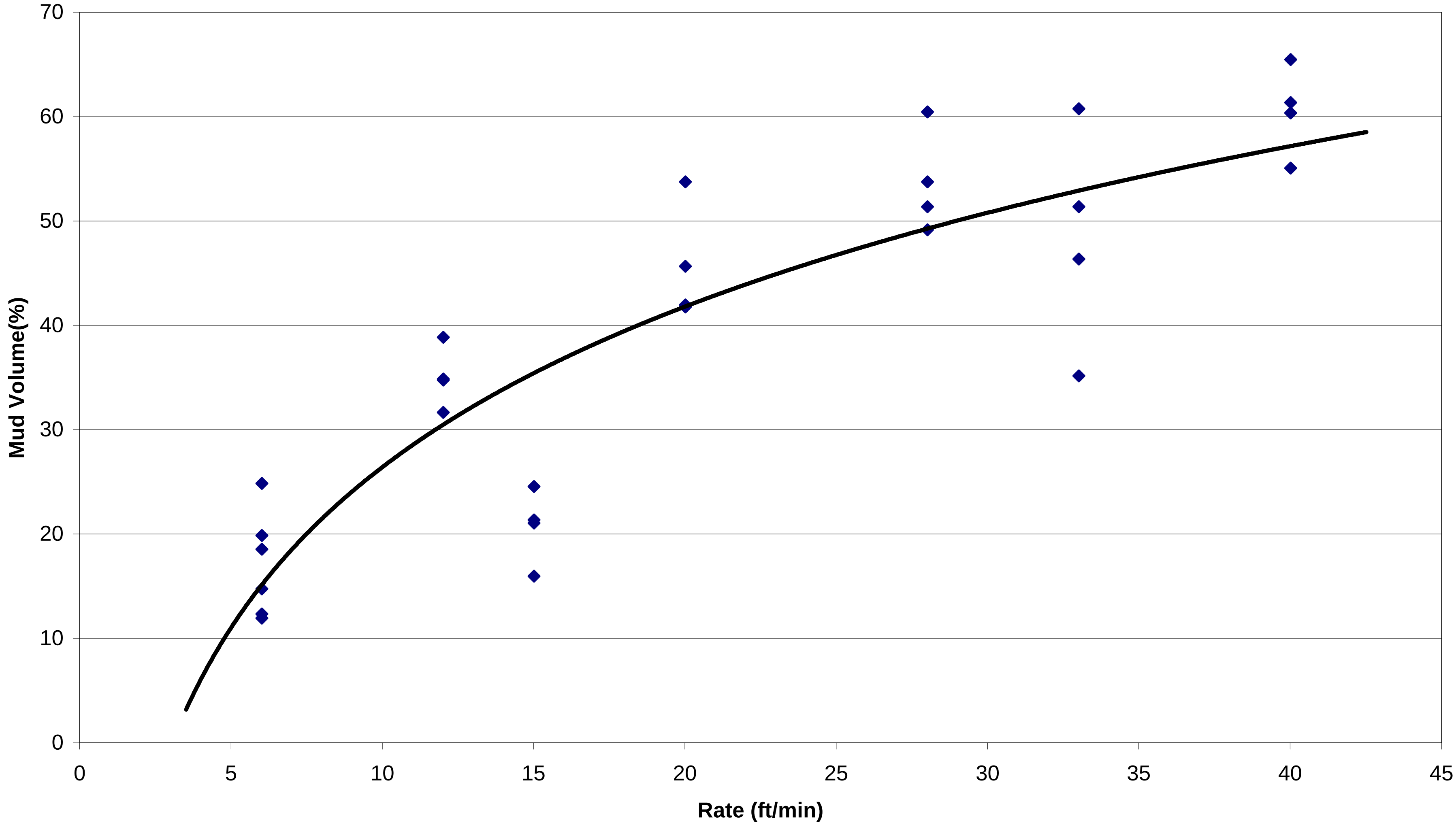


Figure 5-10 Percent of Mud Volume in Dredge Slurry



5.5 IMPACT OF WEATHER AND LAKE CONDITIONS ON PILOT DREDGING

High winds, rough lake conditions, and shallower-than-expected channel depths significantly impacted pilot dredging and support operations throughout most of the period. Temperature conditions were generally typical for the season, but the three-week field demonstration period was characterized by two frontal passages and sustained winds of 12–20 knots per second (kts) for most of the test period. It was noted that in this very shallow lake, sustained winds of even 12 kts were sufficient to stir up 2–3 ft [0.61– 0.91m] waves on the lake surface, thus impacting the safe operation of the relatively small dredge and the smaller utility boats (used to reposition the travel cable for the dredge and tend the floating 6 in [15 cm] line used to transfer the dredged material to the tank barge).

After experiencing almost continuous weather delays, three additional spud barges were mobilized to the PDS. A tug was used to reposition the spud and tank barges in accordance with the wind direction, to provide a lee to protect the dredge and utility equipment from wind and sea. It was evident that under the prevailing weather conditions it would be necessary to remove the dredge, transfer line, and all utility equipment and boats from the water each night, and to reposition the equipment each morning. All of this cost a number of lost days and added significantly to the time and effort required for setup each day.

In addition, perhaps a result of the sustained (predominantly) easterly winds, the water depths in the channel were a good deal lower than had been measured in our earlier surveys. The tug frequently could be heard contacting the bottom well within the channel approaching the Port Mayaca Lock. On one occasion, it was hard aground in this area. The verified draft of this tug was 7 ft [2.13 m]. As a result, we further limited the draft of the tank barge to 6 ft [1.83 m]. This reduced its maximum loading and added to the number of unload cycles.

Finally, the location of a representative pilot dredging area with a sufficient mud layer thickness was determined to be no closer than five miles [8 km] off the eastern shore of the Lake, as opposed to the one mile specified in the contract. This increased the transit time associated with every operation throughout the project.

It is important to note that the majority of these effects would not likely impact a full-scale dredging operation as they did this pilot program. The pilot program necessarily involved smaller equipment and a transfer method far different from those likely to be used in a full-scale operation. The onset of difficulty for our operation occurred at sustained winds of only 10 kts. In addition, a full-scale operation is likely to use a semi-permanent anchored line for pumping dredged materials to the designated treatment/storage area(s). This will make the concentration of the muds in the center of the lake a net advantage for such an operation.

It must be noted that the weather delays experienced during this project were exacerbated due to the scaled-down size of the dredge equipment and the cabling system used to move the dredge. A full scale dredge unit would be expected to far less vulnerable to weather related impacts.

5.6 CONCLUSIONS FROM THE FIELD DEMONSTRATION

As discussed earlier, the SEDCUT® dredge head was successfully able to remove the targeted mud layer without the addition of any significant amounts of dilution water or sands. Thus, the primary project objective, which was to demonstrate the effectiveness of the innovative SEDCUT® technology in selectively removing the mud layer, has been achieved. Significant observations from the field demonstration and recommendations for scaling the process are discussed further in Chapter 9.

Selected photos from the pilot dredging field demonstration are shown in Appendix C.

6.0 ENVIRONMENTAL MONITORING

6.1 WATER QUALITY MONITORING

The goal of the water quality program was to determine:

- Impacts on in-lake water quality resulting from operation of the SEDCUT® dredge head, and
- Efficacy of the selected water treatment technology in reducing total phosphorus concentrations.

The field program therefore included water quality monitoring associated with the following three components:

- In-Lake Water Quality Monitoring
- Field Turbidity Monitoring
- Pilot Water Treatment System Influent & Effluent Quality Monitoring

6.1.1 In-Lake Water Quality Monitoring

In-lake water samples from the PDS were collected and analyzed for selected parameters to assess the impact of dredging operations on site-specific water quality. Four rounds of water quality sampling were conducted during the field demonstration as follows:

- Round 1 (pre-dredge baseline samples) was collected prior to start of dredging;
- Rounds 2 and 3 (active dredging samples) were conducted concurrent with active dredging operations; and
- Round 4 (post-dredge samples) was conducted 24 hours after the field demonstration was completed.

On each day of field sampling, in-lake water quality samples were collected from the following three locations:

- Within 600 ft upwind (upstream) of the PDS,
- Within 100 ft radius of the point of active dredging, and
- Within 600 ft downwind (downstream) of the PDS.

At each of the three locations, a discrete water sample was collected from the following three depths using a Niskin water-sampling bottle:

- 1 ft below surface
- mid-depth
- 1 ft above the bottom

The three discrete depth samples from each location were composited into one sample and aliquots were drawn for analyses of the following parameters:

Inorganics (including Nutrients)

- Alkalinity
- Hardness
- Fecal Coliform
- Total Suspended Solids
- Total Organic Carbon (TOC)
- Total Kjeldahl Nitrogen (TKN)
- Nitrate + Nitrite (total)
- Nitrate + Nitrite (dissolved) [1]
- Ammonia (dissolved)[1]
- Total phosphorus
- Dissolved phosphorus
- Orthophosphorus

[1] Dissolved NH_4 and dissolved NO_2+NO_3 will be measured to determine dissolved inorganic nitrogen.

Metals

- Aluminum (total)
- Arsenic (total)
- Beryllium (total)
- Cadmium (total)
- Chromium (total)
- Copper (total)
- Iron (total)
- Lead (total)
- Mercury (total)[2]
- Nickel (total)
- Selenium (total)
- Silver (total)
- Zinc (total)

[2] Regular analyses only—no trace analyses were conducted.

Samples were shipped to PPB Laboratories on ice for chemical analyses using an overnight delivery service. Sample collection, handling, and shipping were conducted in accordance with the protocol contained in the Lake Okeechobee Water Quality Monitoring Plan (EA, 2001d).

Concurrent with collecting a water quality sample, the following parameters were also measured and recorded in the field at each location:

Parameter	Instrument
Station Location	Garmin DGPS, 12 Channel
Current Velocity	Flo-Mate Model 2000
Temperature	Horiba U-10
pH	Horiba U-10
Dissolved Oxygen	Horiba U-10
Conductivity	Horiba U-10
Turbidity	Lamotte Turbiditymeter, Model 2020
Secchi Depth	Standard 8-inch Black & White Secchi Disk with Calibrated Line

Note that current velocity, temperature, pH, dissolved oxygen, conductivity, and turbidity were measured at three discrete depths; namely 1 ft below surface, mid-depth, and 1 ft above the bottom.

In addition, the following data were collected during the monitoring program at each of the three sampling locations:

- Wind direction and wind speed using a Kestrel hand-held anemometer (model 1000)
- Wave direction and wave height (measured against the PDS pilings)

Atmospheric temperature data for each day of monitoring was obtained from the National Weather Service Station at Miami.

6.1.2 Field Turbidity Monitoring

The field turbidity monitoring plan was designed to track the turbidity plume resulting from resuspension of sediments caused by operation of the innovative dredge head. It must be emphasized that, the turbidity plume not only results from the operation of the actual dredging unit, but also receives contributions from the movement of ancillary marine equipment. During the Pilot Dredging Project, every effort was made operationally to reduce resuspension of sediments from the prop wash of tugs-tenders, barge movement or other operations not directly involved in the actual dredging operations. Also, the field crew took utmost care to minimize water column disturbances during transit from one location to another, and while recording data at each location.

Four rounds of field turbidity monitoring were conducted, concurrent with the field demonstration, on four separate days. Each round (day) of turbidity monitoring involved collecting three sets of samples for measurement of in-lake water column turbidity.

- The first set was collected prior to start of dredging; the values from this set were used to establish baseline conditions for a given day.
- The second set was collected concurrent with active dredging operations.
- The third set was collected at the end of the day after dredging operations had been completed and the transfer barge and all other vessels had left the area; these values were used to determine residual turbidity disturbances.

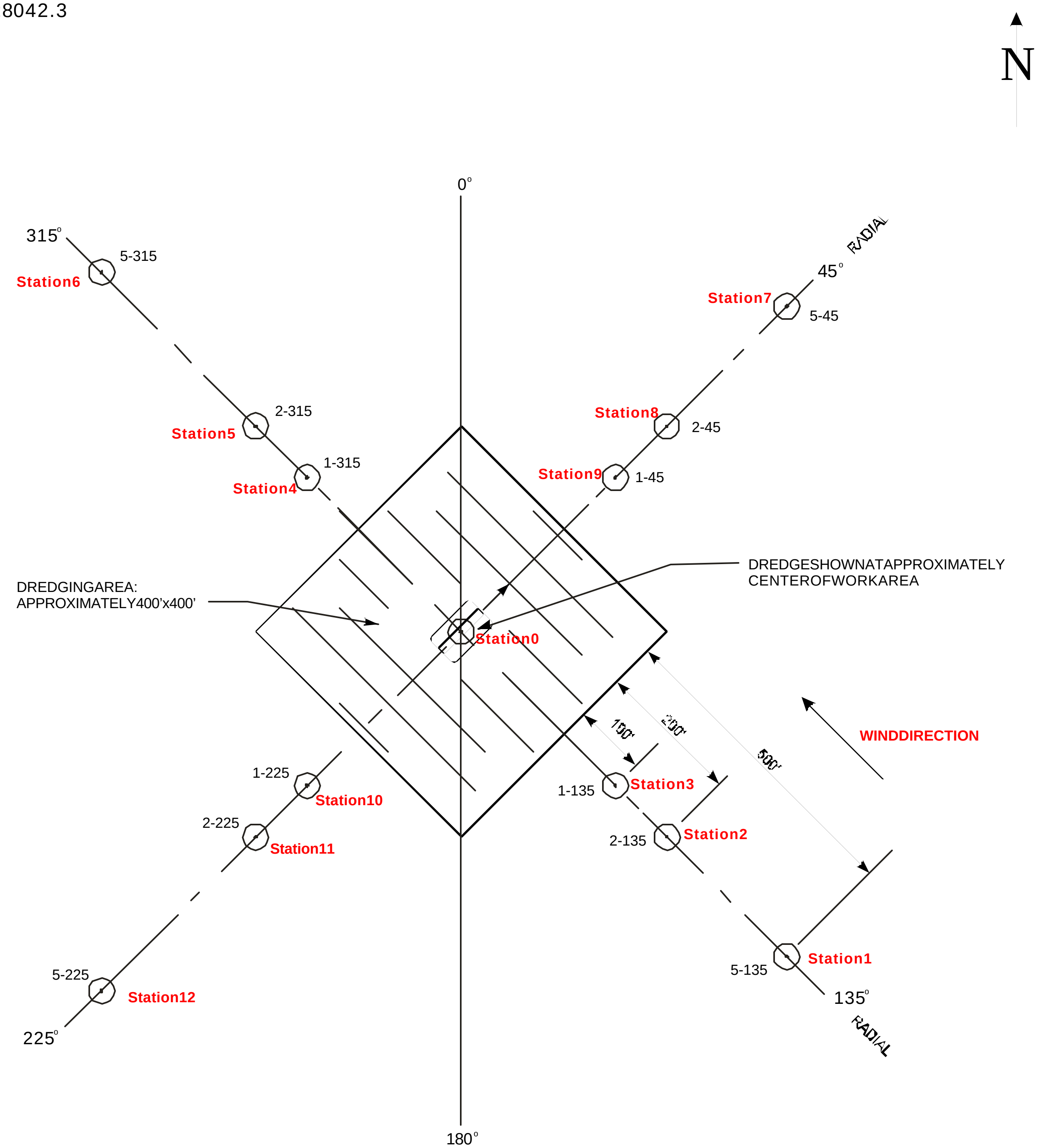
During each set, turbidity measurements were recorded at 13 stations located within a symmetrical 90-degree quadrant pattern that surrounded the PDS (Figure 6-1) using the following methodology:

1. During each of the three monitoring rounds on a given day, the first set of measurements were taken at the dredge directly over the dredge head to obtain source strength associated with the dredging operation.
2. Using a hand-held anemometer, direction and intensity of the wind was determined and the sampling crew proceeded to the farthest monitoring station (i.e. the most upwind station) along the radial line that best aligned with the observed wind direction.
3. Samples for turbidity measurements were drawn at this upwind station from three discrete depths, 1-foot below the surface, mid-depth, and 1-foot above the bottom using a Niskin water sampling bottle.
4. The crew will then moved to the next monitoring station in the downwind direction and measure and record the turbidity at the same three depth intervals.
5. Thus if the wind was blowing out of the north, turbidity monitoring would began at northernmost upwind location (i.e. 5-00) progressing downwind along a north-south radial line in the following order: 5-00, 2-00, 1-00, 1-180, 2-180, and 5-180.

6. Following this, turbidity measurements were recorded on a track line normal to the initial track line, e.g. 5-225, 2-225, 1-225, 1-45, 2-45, 5.45.
7. Thus a total of 117 (3 depths x 13 stations x 3 rounds) field turbidity measurements were recorded on each one of the four days in an approximate 1,000-foot diameter field surrounding the dredging area.

Turbidity was measured with a Lamotte Turbiditymeter (Model 2020). Each set of turbidity monitoring lasted for 90 to 120 minutes.

Latitude:2657.0
Longitude:8042.3



NOTES:

1. Eachcirclerepresentsoneofthethirteenturbiditysamplingstations.
2. Therewerenofixedsamplingstations.Thefigurerepresentsonlytherelativepositionsofthesamplingstations aroundthedredgehead.
3. Onlythedistancebetweenthestationsandtherelativepositionsremainedunchangedfromonedaytothenext. Theactualstationsmovedwiththepositionofthedredgehead(Station0).
4. Thesequenceinwhichthestationsweresampledchangeddailydependinguponthedirectionofthewind;Station0wasalwaysclosetothedredgehead.Station1wasalwaystheupwind location,stations2to6followedthegradientofthewinddirection. Stations7to13weresampledonatransectperpendicular tothewindgradient.
5. Inthesamplingsequenceshownabove,thedredgeheadispositioned approximatelyatthecenteroftheworkarea,theactualpositionofthe dredgeheadchangeddailyandthereforethelocationofSamplingStation0alsochangeddailyandalongwiththelocat ionsofthe other12stationsalsochangedonadailybasis.

EAEngineering,Science, andTechnology,Inc.	LAKEOKEECHOBEEPILOTDREDGINGPROJECT SchematicShowingLocations ForFieldTurbidityMonitoring	DESIGNEDBY JC	DRAWNBY BPG	DATE 8/17/01	PROJECTNO. 61507.01
		CHECKEDBY JC	PROJECTMGR. AK	SCALE NTS	FIGURE 6-1

6.1.3 PWTS Influent & Effluent Quality Monitoring

Influent and effluent samples from the PWTS were analyzed for a suite of water quality parameters to determine the impact of treatment on lake readiness of the PWTS effluent. Four sets of influent and effluent samples were collected from the system and analyzed for alkalinity, hardness, fecal coliform, TOC, TKN, nitrate and nitrite (total and dissolved), ammonia (dissolved), and dissolved Phosphorus (P).

Supplementary details on water quality sample collection, handling, and shipping are contained in the *Lake Okeechobee Pilot Dredging Project – Water Quality Monitoring Plan* (EA, 2001d).

6.1.4 Field Sampling Quality Assurance/Quality Control (QA/QC)

Three different types of field QA/QC samples were collected and analyzed to ensure that water quality sampling was conducted in accordance with established protocols, which were used as guidelines in developing the field monitoring plan.

1. **Field Blanks** – Field blanks were collected to evaluate the impact of sampling activities and environment on the samples collected. One field blank per day of sampling was collected at a location within a 100-ft radius of the proposed point of dredging (active dredging zone). This QC sample was collected by pouring deionized water into a sample container and keeping it open until sampling at that station was completed. The field blank sample was then preserved, as appropriate, and handled like a routine sample along with all other samples. It was analyzed for the same suite of analytes as the In-Lake water quality sample collected at this location.

2. **Equipment Blanks** – To evaluate the effectiveness of laboratory decontamination, equipment blanks were collected at the start of each field sampling day. One equipment blank was collected at the start of each field sampling day, at the upstream/upwind location. This QC sample was collected by pouring deionized water over each piece of water sampling equipment that had been decontaminated using the procedure outlined in the plan. The equipment blank was shipped to the analytical laboratory along with the other samples and was analyzed for the same suite of analytes as the In-Lake water sample collected at the upstream/upwind location.

3. **Field Duplicates** – These are generally intended to evaluate sampling precision and field variability. One field duplicate was collected concurrent with the sample collected within the active dredging zone on each day of sampling. The duplicate sample was analyzed for the same suite of analytes as the in-lake water quality sample collected at this location.

   Field duplicates were also collected in parallel with samples collected from the PWTS effluent stream.

6.1.5 Water Quality Monitoring Results

Results from laboratory analyses of in-lake water quality sampling are presented in Tables 6-1 to 6-4. Measurements of field water quality parameters are listed in Tables 6-5 to 6-8. Tables 6-9 to 6-12 show raw data from the field turbidity monitoring program. Graphical representations of the turbidity data are illustrated in Figures 6-2 to 6-13. Tables 6-13 to 6-16 contain data on PWTS influent and effluent water quality. Raw data from the laboratory are included in Appendix D.

Laboratory results from analyses of influent and effluent samples collected from the pilot water treatment system are discussed in Chapter 8. Significant observations from the water quality analyses are presented and discussed in Chapter 9.

Table 6-1 In-Lake Water Quality Monitoring Data (May 08, 2002)

Parameters	Units	Station ID: Upwind/ Upstream	Station ID: Dredging Area	Station ID: Downwind/ Downstream	Field Duplicate[1]	Field Blank	Equipment Blank	FDEP Water Quality Criteria[2,3]
Alkalinity	mg/l	130	130	128	129	3	3	
TOC	mg/l	56.6	56.8	56.3	57.3	<2.00	<2.00	
Fecal Coliforms	MPN/100 ml	<2 Q	<2 Q	NR	<2 Q	<2 Q	<2 Q	
Hardness	mg/l	195	192	200	204	<1	<1	
Ammonia (dissolved)	mg/l	0.059	0.066	0.061	0.050	0.02 IQ	0.03Q	
TKN	mg/l	1.55	1.52	1.5	1.66	<0.10	<0.10	
$NO_2 + NO_3$	mg/l	0.031	0.028	0.03	0.024	<0.004	<0.004	
$NO_2 + NO_3$ (dissolved)	mg/l	0.047	0.033	0.029	0.019	0.111 Q	- -	
Inorganic N (dissolved)[4]	mg/l	0.106	0.099	0.09	0.069	0.121	0.03	
Total Phosphorus	mg/l	0.138	0.145	0.148	0.142	<0.004	<0.004	
Dissolved Phosphorus	mg/l	0.092	0.095	0.141	0.159	<0.004	0.003 I	
Orthophosphorus	mg/l	0.076	0.053	0.057	0.053	<0.004	<0.004	
TSS	mg/l	17	14	16	17	<2	<2	
Aluminum (total)	ug/l	528	503	490	446	<20	<20	
Arsenic (total)	ug/l	2.6 I	<2.5	<2.5	2.8I	<2.5	<2.5	<50
Beryllium (total)[5]	ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.0077
Cadmium (total)	ug/l	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	2.07
Chromium (total)	ug/l	1.1 I	1.1	1 I	1 I	<0.5	<0.5	387
Copper (total)	ug/l	2.9	2.9	2.9	2.7	<1.5	<1.5	22.7
Iron (total)	ug/l	743	767	767	704	<2.5	<2.5	3,000
Lead (total)	ug/l	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	8.43
Mercury (total)[5]	ug/l	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.012
Nickel (total)	ug/l	<1.4	<1.4 I	<1.4	1.7 I	<1.4	<1.4	301
Selenium (total)	ug/l	<1.4	<1.4	<1.4	1.6 I	<1.4	<1.4	<5
Silver (total)[5]	ug/l	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.07
Zinc (total)	ug/l	10.6	8.5	12.2	9.1	3.8 I	2.6 I	203

Notes

[1]Field duplicate was collected in the dredging area.

NR = Analysis not required.

[2]As established by the Florida Administrative Code (FAC) 62-302.400.

[3]For cadmium, chromium, copper, lead, nickel, and zinc the criteria was recalculated for an average hardness of 215 mg/L

[4]Dissolved inorganic nitrogen calculated as sum of dissolved ammonia and dissolved nitrate + nitrite.

[5]FDEP's water quality criteria are lower than the detection limit.

-- Sample could not be analyzed due to laboratory error.

Q = Result analyzed out of holding time.

I = Result between detection limit and practical quantitation limit.

Table 6-2 In-Lake Water Quality Monitoring Data (May 21, 2002)

Parameters	Units	Station ID: Upwind/ Upstream	Station ID: Dredging Area	Station ID: Downwind/ Downstream	Field Duplicate[1]	Field Blank	Equipment Blank	FDEP Water Quality Criteria[2,3]
Alkalinity	mg/l	128	132	126	122	2 I	2 I	
TOC	mg/l	30.8	30.8	29.6	30.5	<1.00	<1.00	
Fecal Coliforms	MPN/100 ml	- -	- -	- -	- -	- -	- -	
Hardness	mg/l	224	216	228	220	<1.0	<1.0	
Ammonia (dissolved)	mg/l	0.031	0.043	0.073	0.049	0.025	0.016 I	
TKN	mg/l	2.58	2.14	2.39	2.48	<0.10	<0.10	
$NO_2 + NO_3$	mg/l	0.188	0.187	0.197	0.197	<0.004	<0.004	
$NO_2 + NO_3$ (dissolved)	mg/l	0.262	0.231	0.266	0.216	0.011 I	0.004 I	
Inorganic N (dissolved)[4]	mg/l	0.293	0.274	0.339	0.265	0.036	0.02	
Phosphorus (total)	mg/l	0.422	0.298	0.27	0.286	<0.004	0.008 I	
Phosphorus (dissolved)	mg/l	0.067	0.069	0.069	0.078	0.008 I	<0.004	
Orthophosphorus	mg/l	0.102	0.107	0.107	0.111	<0.004	<0.004	
TSS	mg/l	93	20	21	101 Q	<2	<2	
Aluminum (total)	ug/l	3300	1732	1740	2060	<20	<20	
Arsenic (total)	ug/l	<2.5	2.5 I	<2.5	<2.5	<2.5	<2.5	<50
Beryllium (total)[5]	ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.0077
Cadmium (total)	ug/l	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	2.07
Chromium (total)	ug/l	5.5	3.3	3.2	3.8	<0.5	<0.5	387
Copper (total)	ug/l	5.7	5.1	6.4	5.3	<1.5	<1.5	22.7
Iron (total)	ug/l	3230 [6]	2507	2250	2630	<2.5	<2.5	3,000
Lead (total)	ug/l	3.9 I	2.8 I	<2.4	2.6 I	<2.4	<2.4	8.43
Mercury (total)[5]	ug/l	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.012
Nickel (total)	ug/l	4.3 I	2.5 I	3.1 I	2.5 I	<1.4	<1.4	301
Selenium (total)	ug/l	<1.4	<1.4	2 I	1.6 I	<1.4	<1.4	<5
Silver (total)[5]	ug/l	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.07
Zinc (total)	ug/l	25	23.3	19.1	33.5	<1.6	<1.6	203

Notes

[1]Field duplicate was collected in the dredging area.

[2]As established by the Florida Administrative Code (FAC) 62-302.400.

[3]For cadmium, chromium, copper, lead, nickel, and zinc the criteria was recalculated for an average hardness of 215 mg/L

[4]Dissolved inorganic nitrogen calculated as sum of dissolved ammonia and dissolved nitrate + nitrite.

[5]FDEP's water quality criteria are lower than the detection limit.

[6]Iron concentrations at the upstream location exceeded the FDEP wate quality criteria.

- - Samples damaged during shipping; could not be analyzed.

Q = Result analyzed out of holding time.

I = Result between detection limit and practical quantitation limit.

Table 6-3 In-Lake Water Quality Monitoring Data (May 27, 2002)

Parameters	Units	Station ID: Upwind/ Upstream	Station ID: Dredging Area	Station ID: Downwind/ Downstream	Field Duplicate[1]	Field Blank	Equipment Blank	FDEP Water Quality Criteria[2,3]
Alkalinity	mg/l	136	132	134	132	2 I	2 I	
TOC	mg/l	28.2	37	26.6	25.1	<1.00	<1.00	
Fecal Coliforms	MPN/100 ml	2 IQ	2 IQ	4 IQ	2	NR	<2	
Hardness	mg/l	224	216	224	212	<1.0	<1.0	
Ammonia (dissolved)	mg/l	0.037	0.014 I	0.035	0.016 I	0.006 I	<0.005	
TKN	mg/l	2.14	1.37	1.69	1.77	<0.10	<0.10	
$NO_2 + NO_3$	mg/l	0.207	0.199	0.184	0.198	<0.004	<0.004	
$NO_2 + NO_3$ (dissolved)	mg/l	0.21	0.195	0.161	0.231	0.009 I	0.004 I	
Inorganic N (dissolved)[4]	mg/l	0.247	0.209	0.196	0.247	0.015	0.009	
Total Phosphorus	mg/l	0.268	0.271	0.271	0.28	<0.004	<0.004	
Dissolved Phosphorus	mg/l	0.086	0.069	0.069	0.061	<0.004	<0.004	
Orthophosphorus	mg/l	0.103	0.11	0.115	0.108	<0.004	<0.004	
TSS	mg/l	63	48	48	57	<2	<2	
Aluminum (total)	ug/l	1110	987	1020	1070	<20	<20	
Arsenic (total)	ug/l	3.6 I	<2.5	<2.5	2.9 I	<2.5	<2.5	<50
Beryllium (total)[5]	ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.0077
Cadmium (total)	ug/l	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	2.07
Chromium (total)	ug/l	2.6	2.1	1.8 I	1.9 I	<0.5	<0.5	387
Copper (total)	ug/l	6.5	3.1	2.9	3.7	<1.5	<1.5	22.7
Iron (total)	ug/l	1720	1620	1580	1720	<2.5	<2.5	3,000
Lead (total)	ug/l	3 I	<2.4	3.1 I	2.9 I	<2.4	<2.4	8.43
Mercury (total)[5]	ug/l	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.012
Nickel (total)	ug/l	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	301
Selenium (total)	ug/l	2.5 I	<1.4	1.8 I	3.8 I	1.6 I	2.6 I	<5
Silver (total)[5]	ug/l	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.07
Zinc (total)	ug/l	17.3	13.7	7.1	16.3	<1.6	<1.6	203

Notes

[1]Field duplicate was collected in the dredging area.

[2]As established by the Florida Administrative Code (FAC) 62-302.400.

[3]For cadmium, chromium, copper, lead, nickel, and zinc the criteria was recalculated for an average hardness of 215 mg/L

[4]Dissolved inorganic nitrogen calculated as sum of dissolved ammonia and dissolved nitrate + nitrite.

[5]FDEP's water quality criteria are lower than the detection limit.

NR = Analysis not required.

I = Result between detection limit and practical quantitation limit.

Q = Result analyzed out of holding time.

Table 6-4 In-Lake Water Quality Monitoring Data (May 30, 2002)

Parameters	Units	Station ID: Upwind/ Upstream	Station ID: Dredging Area	Station ID: Downwind/ Downstream	Field Duplicate[1]	Field Blank	Equipment Blank	FDEP Water Quality Criteria[2,3]
Alkalinity	mg/l	132	134	132	134	2 I	2 I	
TOC	mg/l	24.9	24.9	23	23.6	<1.00	<1.00	
Fecal Coliforms	MPN/100 ml	8 IQ	<2 Q	4 IQ	2 IQ	<2 Q	<2 Q	
Hardness	mg/l	204	216	204	212	<1.0	<1.0	
Ammonia (dissolved)	mg/l	0.056	0.048	0.066	0.063	0.031	0.052	
TKN	mg/l	1.49	1.33	1.12	1.1	0.11 I	<0.10	
$NO_2 + NO_3$	mg/l	0.184	0.179	0.176	0.173	<0.004	<0.004	
$NO_2 + NO_3$ (dissolved)	mg/l	0.162	0.191	0.191	0.188	0.005 I	0.011 I	
Inorganic N (dissolved)[4]	mg/l	0.218	0.239	0.257	0.251	0.036	0.063	
Total Phosphorus	mg/l	0.192	0.204	0.216	0.192	<0.004	<0.004	
Dissolved Phosphorus	mg/l	0.081	0.067	0.111	0.069	<0.004	<0.004	
Orthophosphorus	mg/l	0.076	0.077	0.075	0.076	<0.004	<0.004	
TSS	mg/l	20	16	13	16	<2	<2	
Aluminum (total)	ug/l	739	687	730	910	<20	<20	
Arsenic (total)	ug/l	3.4 I	2.6 I	3.2 I	<2.5	<2.5	<2.5	<50
Beryllium (total)[5]	ug/l	0.3 I	0.3 I	0.27 I	<0.2	<0.2	<0.2	<0.0077
Cadmium (total)	ug/l	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	2.07
Chromium (total)	ug/l	1.3 I	1.2 I	1.3 I	1.3 I	<0.5	<0.5	387
Copper (total)	ug/l	4.3	4.5	4.1	4.4	<1.5	<1.5	22.7
Iron (total)	ug/l	1130	1060	1090	1110	<2.5	3.8 I	3,000
Lead (total)	ug/l	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	8.43
Mercury (total)[5]	ug/l	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.012
Nickel (total)	ug/l	1.9 I	2.5 I	2.7 I	1.9 I	<1.4	<1.4	301
Selenium (total)	ug/l	<1.4	2.1 I	2.1 I	<1.4	<1.4	<1.4	<5
Silver (total)[5]	ug/l	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.07
Zinc (total)	ug/l	4.8 I	3.8 I	3 I	4.2 I	<1.6	<1.6	203

Notes

[1]Field duplicate was collected in the dredging area.

[2]As established by the Florida Administrative Code (FAC) 62-302.400.

[3]For cadmium, chromium, copper, lead, nickel, and zinc the criteria was recalculated for an average hardness of 215 mg/L

[4]Dissolved inorganic nitrogen calculated as sum of dissolved ammonia and dissolved nitrate + nitrite.

[5]FDEP's water quality criteria are lower than the detection limit.

I = Result between detection limit and practical quantitation limit.

Q = Result analyzed out of holding time.

Table 6-5 In-Lake Field Parameters Monitoring Data (May 8, 2002)

Date & Time: 05/08/02; 1:38 pm
Sampling Personnel: LG, IS, KH
Weather conditions: Partly cloudy, 87ºC
Wind Direction: 322º
Wind Speed: 6.04 knots
Wave Height: 0.8? - 1.4? (light chop)

Station	Time	Water Column Depth (ft)	Secchi Depth (ft)	Current Velocity (ft/sec)	Water Temp (deg C)	pH (SU)	Dissolved Oxygen (mg/L)	Conductivity (µmho/cm)	Turbidity (NTU)
Station: Upwind/Upstream	3:14 pm	11.0	1.5						
1' below surface				0.61	30.9	8.57	7.13	0.608	--
Mid-depth				0.32	28.8	8.13	7.77	0.610	--
1' above bottom				0.20	29.0	7.30	7.94	0.652	--
Station: Dredge Zone	3:50 pm	11.5	1.5						
1' below surface				0.73	30.1	9.01	7.10	0.606	--
Mid-depth				0.50	28.8	8.70	7.81	0.605	--
1' above bottom				0.15	29.1	8.57	7.90	0.614	--
Station: Downwind/ Downstream	4:17 pm	11.0	1.5						
1' below surface				0.57	30.3	8.98	7.35	0.605	--
Mid-depth				0.57	29.7	8.95	7.48	0.602	--
1' above bottom				0.33	28.5	8.85	7.96	0.607	--

Notes:

1. Sample for fecal coliform broke during shipping (Sample ID: DS20020508).

Table 6-6 In-Lake Field Parameters Monitoring Data (May 21, 2002)

Date & Time: 05/21/02; 10:35 am
Sampling Personnel: LG, IS, BG
Weather conditions: Partly cloudy, 78ºC
Wind Direction: 10º
Wind Speed: 12 knots
Wave Height: 1' - 2' (moderate to heavy chop)

Station	Time	Water Column Depth (ft)	Secchi Depth (ft)	Current Velocity (ft/sec)	Water Temp (deg C)	pH (SU)	Dissolved Oxygen (mg/L)	Conductivity (µmho/cm)	Turbidity (NTU)
Station: Upwind/Upstream	11:25 am	11.0	0.5						
1' below surface				1.18	26.4	8.93	7.76	0.602	81.2
Mid-depth				0.54	26.4	8.97	7.59	0.607	85.6
1' above bottom				0.19	26.2	9.00	7.72	0.644	73.0
Station: Dredge Zone	1:30 pm	11.0	0.5						
1' below surface				1.32	26.9	8.30	8.27	0.649	95.2
Mid-depth				0.47	27.0	8.11	8.19	0.650	90.0
1' above bottom				0.23	27.2	7.56	8.20	0.675	88.5
Station: Downwind/ Downstream	2:45 pm	11.0	0.5						
1' below surface				1.33	27.2	8.51	8.64	0.652	91.0
Mid-depth				0.44	27.0	8.57	9.00	0.653	84.6
1' above bottom				0.09	27.5	8.58	9.36	0.649	62.4

Notes:

Table 6-7 In-Lake Field Parameters Monitoring Data (May 27, 2002)

Date & Time: 05/27/02; 11:15 am
Sampling Personnel: LG, IS
Weather conditions: Partly cloudy, 83ºC
Wind Direction: 90º
Wind Speed: 7.5 knots
Wave Height: ½ ' - 1' (light chop)

Station	Time	Water Column Depth (ft)	Secchi Depth (ft)	Current Velocity (ft/sec)	Water Temp (deg C)	pH (SU)	Dissolved Oxygen (mg/L)	Conductivity (µmho/cm)	Turbidity (NTU)
Station: Upwind/Upstream	11:40 am	10.0	0.5						
1' below surface				0.73	26.8	8.29	8.02	0.633	61.6
Mid-depth				0.70	27.1	8.06	7.96	0.636	56.3
1' above bottom				0.39	27.1	7.94	8.02	0.634	67.4
Station: Dredge Zone	12:18 pm	10.0	0.5						
1' below surface				0.67	26.3	8.50	8.31	0.632	72.0
Mid-depth				0.36	26.2	8.49	8.40	0.633	66.9
1' above bottom				0.17	26.3	8.42	8.38	0.632	81.9
Station: Downwind/ Downstream	1:00 pm	10.0	0.5						
1' below surface				1.17	26.5	8.55	8.29	0.635	54.1
Mid-depth				0.85	26.6	8.54	8.31	0.632	62.1
1' above bottom				0.47	26.3	8.59	8.42	0.631	76.0

Notes:

Table 6-8 In-Lake Field Parameters Monitoring Data (May 30, 2002)

Date & Time: 05/30/02; 12:10 am
Sampling Personnel: LG, IS
Weather conditions: Partly cloudy, 90ºC
Wind Direction: 210º
Wind Speed: 1.9 knots
Wave Height: <½ ' (calm, no chop)

Station	Time	Water Column Depth (ft)	Secchi Depth (ft)	Current Velocity (ft/sec)	Water Temp (deg C)	pH (SU)	Dissolved Oxygen (mg/L)	Conductivity (µmho/cm)	Turbidity (NTU)
Station: Upwind/Upstream	12:30 pm	10.0	1.0						
1' below surface				0.43	28.6	8.65	7.65	0.641	51.4
Mid-depth				0.29	27.4	8.01	8.02	0.664	47.5
1' above bottom				0.08	27.5	8.72	7.94	0.696	56.0
Station: Dredge Zone	1:25 pm	10.5	1.0						
1' below surface				0.53	30.4	8.67	7.08	0.638	47.0
Mid-depth				0.19	28.2	8.61	7.90	0.642	38.9
1' above bottom				0.10	27.3	8.58	8.13	0.642	46.2
Station: Downwind/ Downstream	1:45 pm	10.0	1.0						
1' below surface				0.46	30.2	8.66	7.19	0.648	42.7
Mid-depth				0.23	27.1	8.58	8.06	0.639	39.5
1' above bottom				0.15	27.0	8.59	8.07	0.639	50.0

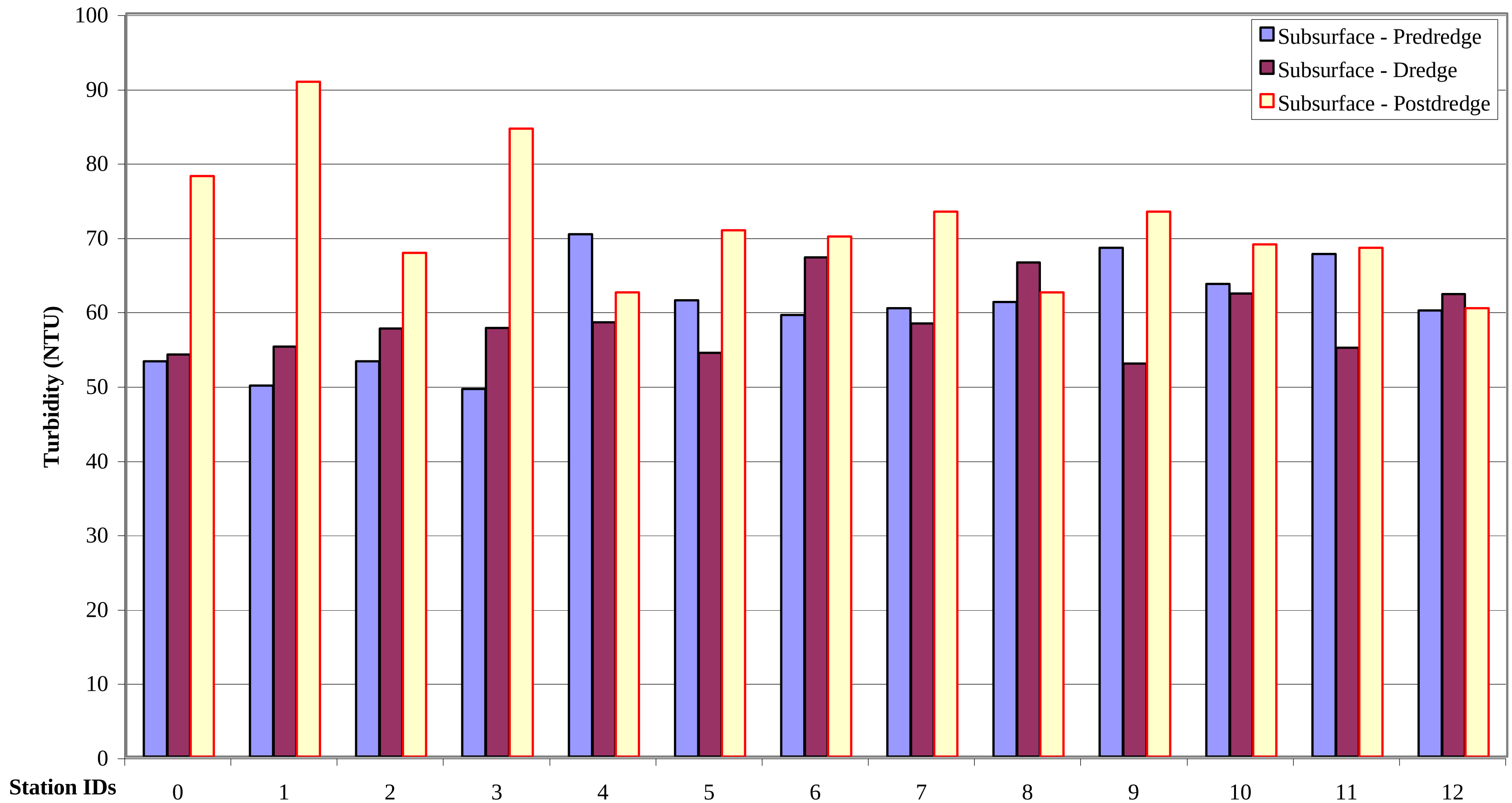
Notes:

Table 6-9 Field Turbidity Monitoring Data (May 25, 2002)

Station ID	Round 1 (Pre-Dredging)			Round 2 (Active Dredging)			Round 3 (Post Dredging)		
	Start Time = 0645, Finish Time = 0805			Start Time =1115, Finish Time = 1310			Start Time =1630, Finish Time = 1800		
	Wave Height = <1/2'			*Wave Height = 1'- 2'*			*Wave Height = 2'- 3'*		
	Wind Direction = NE			*Wind Direction = NE*			*Wind Direction = NE*		
	Subsurface - Predredge	Middepth - Predredge	Bottom - Predredge	Subsurface - Dredge	Middepth - Dredge	Bottom - Dredge	Subsurface - Postdredge	Middepth - Postdredge	Bottom - Postdredge
0	53.2	56.3	176	54.1	58.7	69.6	78.1	87.4	92.4
1	49.9	53.6	65.3	55.2	51.1	56.4	90.8	85.1	86.0
2	53.2	66.1	201	57.6	66.6	59.0	67.8	71.0	78.4
3	49.5	61.6	138	57.7	54.4	56.4	84.5	69.1	71.3
4	70.3	61.5	72.3	58.4	64.7	67.8	62.5	70.1	74.0
5	61.4	63.4	66.7	54.3	58.2	59.1	70.8	71.1	74.1
6	59.4	55.3	79.2	67.2	50.4	62.2	70.0	71.2	76.3
7	60.3	64.2	70.5	58.3	61.3	59.0	73.3	69.9	70.1
8	61.2	69.5	65.1	66.5	61.1	69.2	62.5	70.1	74.0
9	68.5	60.7	58.9	52.9	55.0	60.2	73.3	69.8	71.0
10	63.6	54.8	83.3	62.3	59.5	67.2	68.9	68.2	70.2
11	67.6	54.6	83.8	55.0	54.3	60.9	68.5	65.5	67.2
12	60.0	60.2	68.9	62.2	66.3	68.0	60.3	59.8	63.3

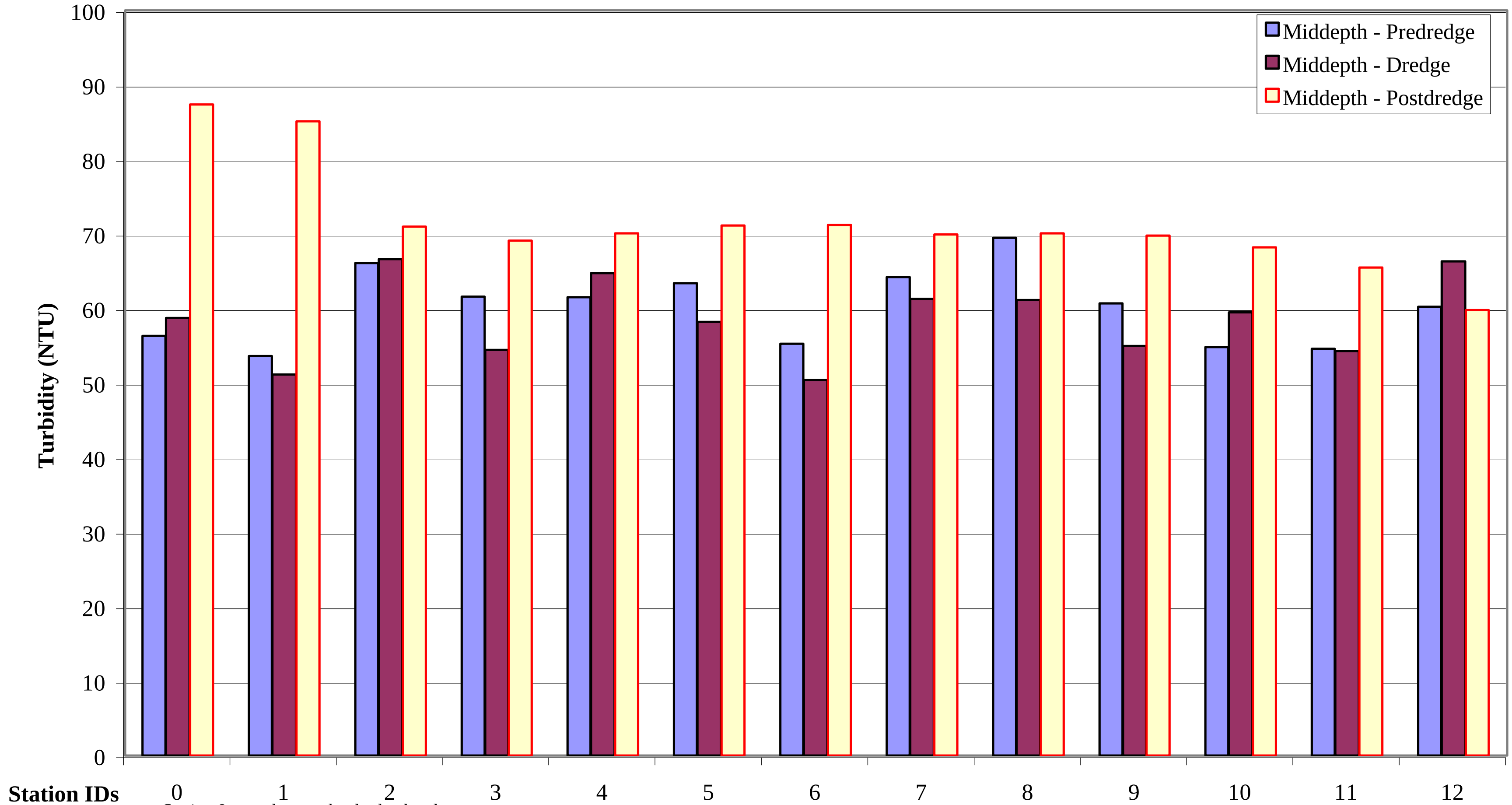
Notes:
1. All readings are in NTU
2. Station ID 0 indicates location adjacent to the dredge head;
3. Stations 1 - 6 were located along a transect following the prevailing wind direction (Station 1- upwind location, Station 6 downwind location).
4. Stations 7-12 were located along a transect that ran perpendicular to the above transect.

Figure 6-2 Field Turbidity Monitoring Data (Subsurface Samples - May 25, 2002)



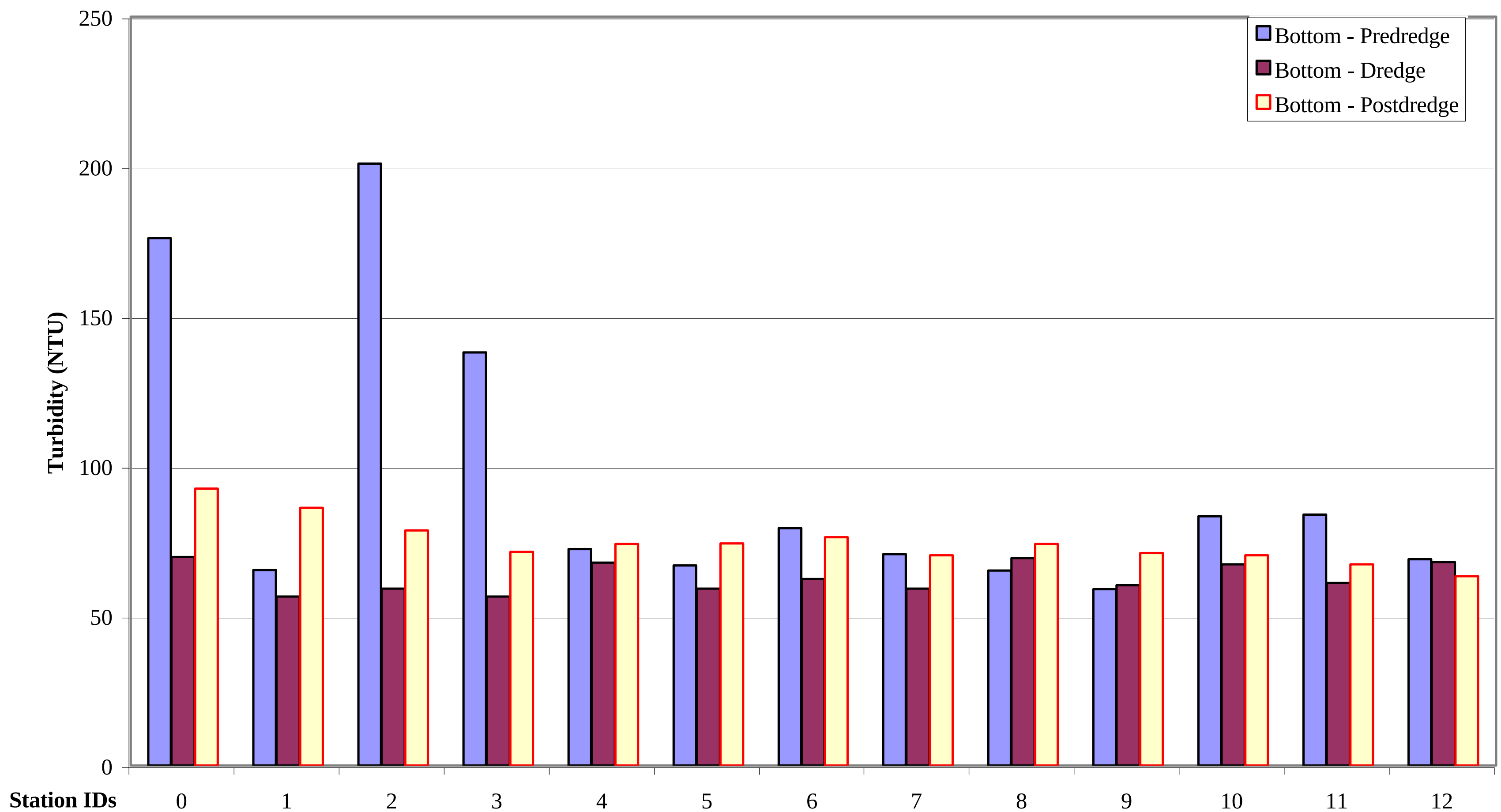
Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Figure 6-3 Field Turbidity Monitoring Data (Mid-depth Samples - May 25, 2002)



Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Figure 6-4 Field Turbidity Monitoring Data (Bottom Samples - May 25, 2002)



Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

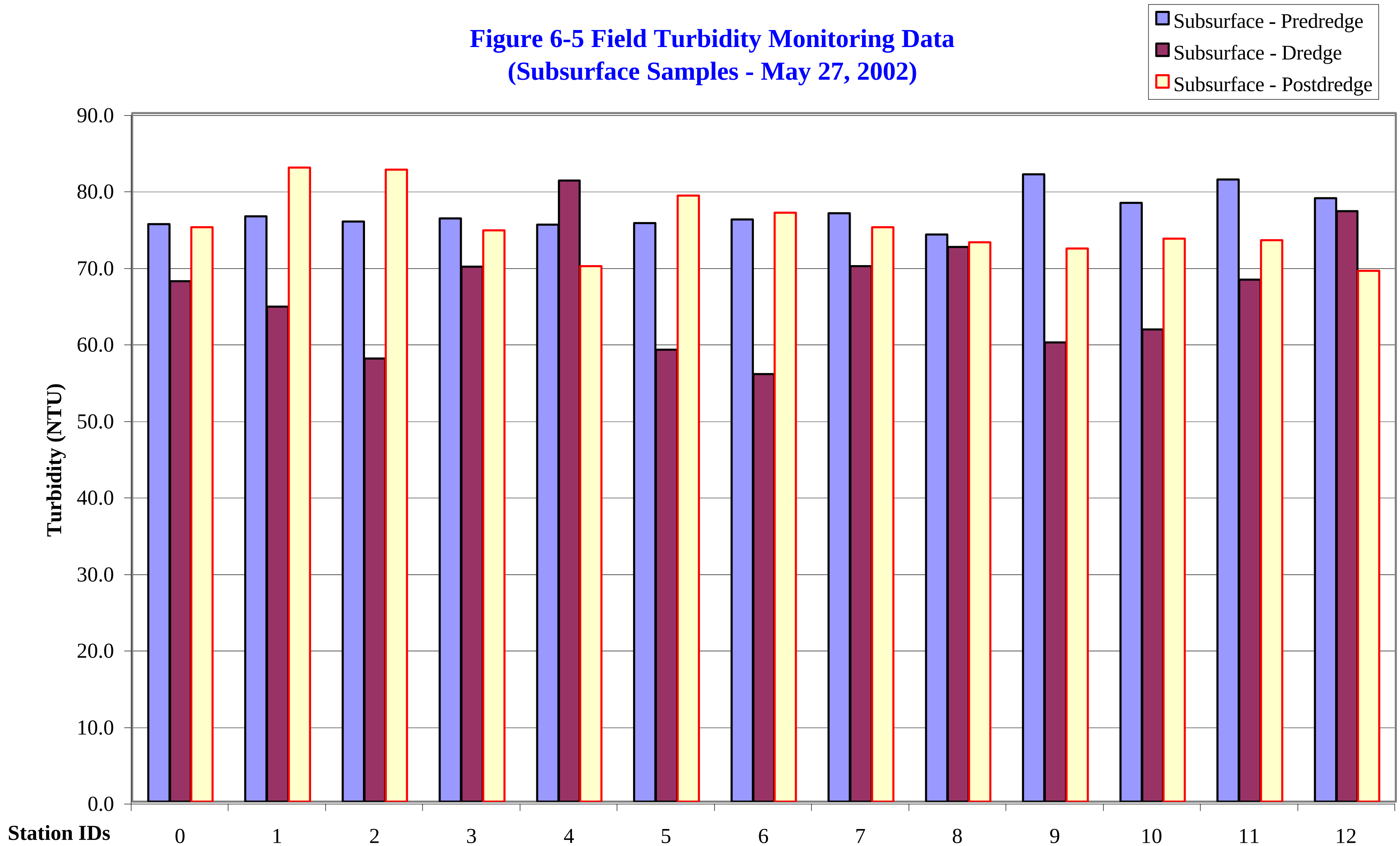
Table 6-10 Field Turbidity Monitoring Data (May 27, 2002)

Station ID	Round 1 (Pre Dredging)			Round 2 (Active Dredging)			Round 3 (Post Dredging)		
	Start Time = 0650, Finish Time =0820			Start Time = 1250, Finish Tim = 1415			Start Time = 1640, Finish Time = 1755		
	Wave Height = 1/2' - 1'			*Wave Height = 2' -4'*			*Wave Height = 4' -5'*		
	Wind Direction = NE			*Wind Direction = NE*			*Wind Direction = NE*		
	Subsurface - Predredge	Middepth - Predredge	Bottom - Predredge	Subsurface - Dredge	Middepth - Dredge	Bottom - Dredge	Subsurface - Postdredge	Middepth - Postdredge	Bottom - Postdredge
0	75.5	78.3	76.6	68.0	92.9	87.4	75.1	74.4	81.7
1	76.5	75.5	85.2	64.7	66.3	54.1	82.9	72.9	84.3
2	75.8	72.8	74.5	57.9	52.4	71.5	82.6	77.7	80.7
3	76.2	67.2	80.5	69.9	67.4	64.6	74.7	76.8	66.1
4	75.4	78.3	77.7	81.2	69.8	67.0	70.0	69.5	76.6
5	75.6	77.2	79.0	59.1	63.3	62.9	79.2	69.3	75.4
6	76.1	72.5	75.3	55.9	57.2	59.3	77.0	76.5	78.1
7	76.9	73.0	76.6	70.0	64.3	70.7	75.1	69.2	70.2
8	74.1	75.5	78.4	72.5	71.2	73.4	73.1	68.4	71.5
9	82.0	76.3	81.0	60.0	60.4	63.9	72.3	73.4	68.5
10	78.3	75.4	78.4	61.7	66.4	57.0	73.6	76.2	72.1
11	81.3	72.6	75.6	68.2	64.3	69.8	73.4	74.9	69.5
12	78.9	78.7	78.2	77.2	71.9	64.5	69.4	71.0	65.2

Notes:

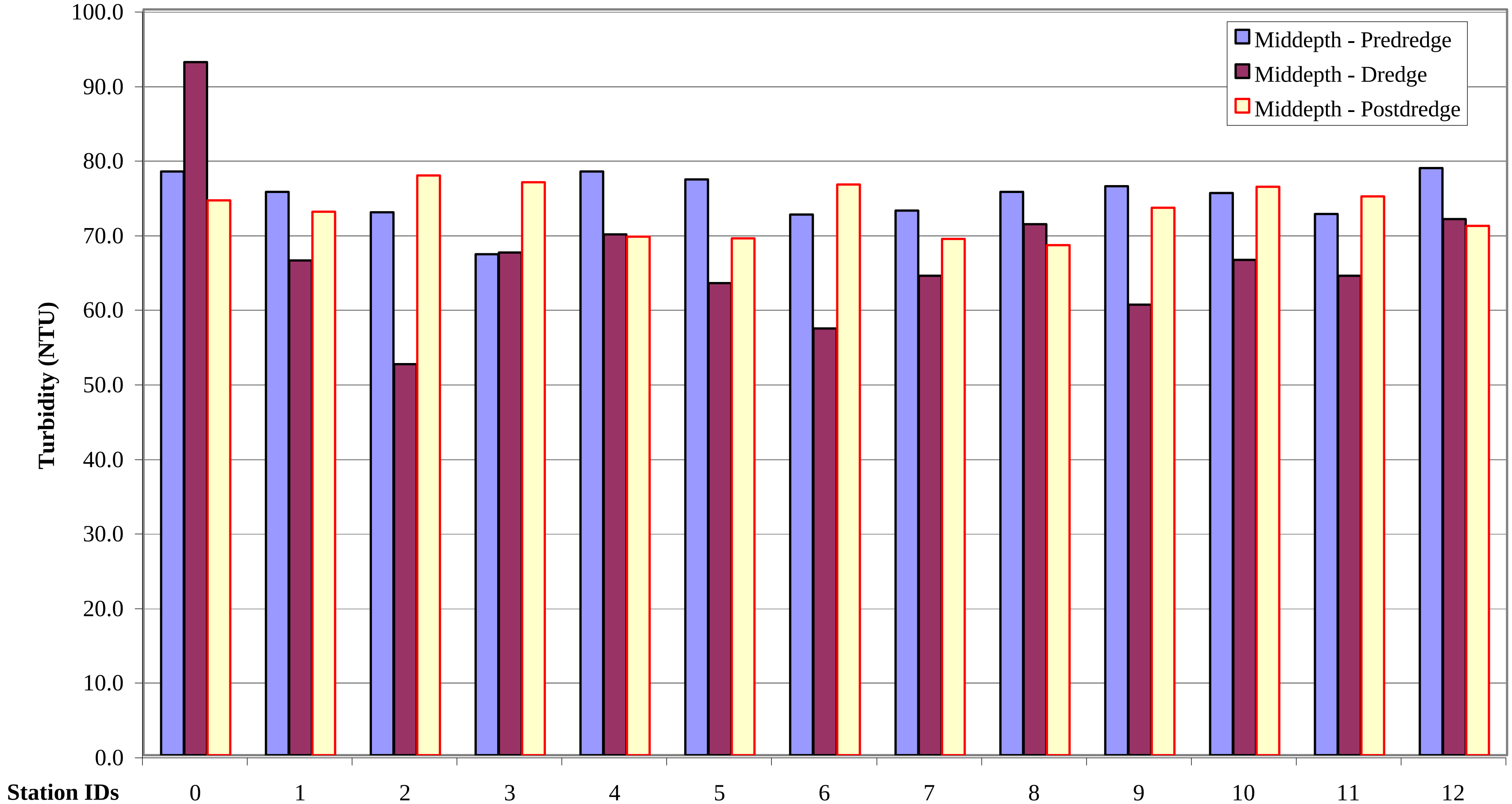
1. All readings are in NTU
2. Station ID 0 indicates location adjacent to the dredge head;
3. Stations 1 - 6 were located along a transect following the prevailing wind direction (Station 1- upwind location, Station 6 downwind location).
4. Stations 7-12 were located along a transect that ran perpendicular to the above transect.

Figure 6-5 Field Turbidity Monitoring Data (Subsurface Samples - May 27, 2002)



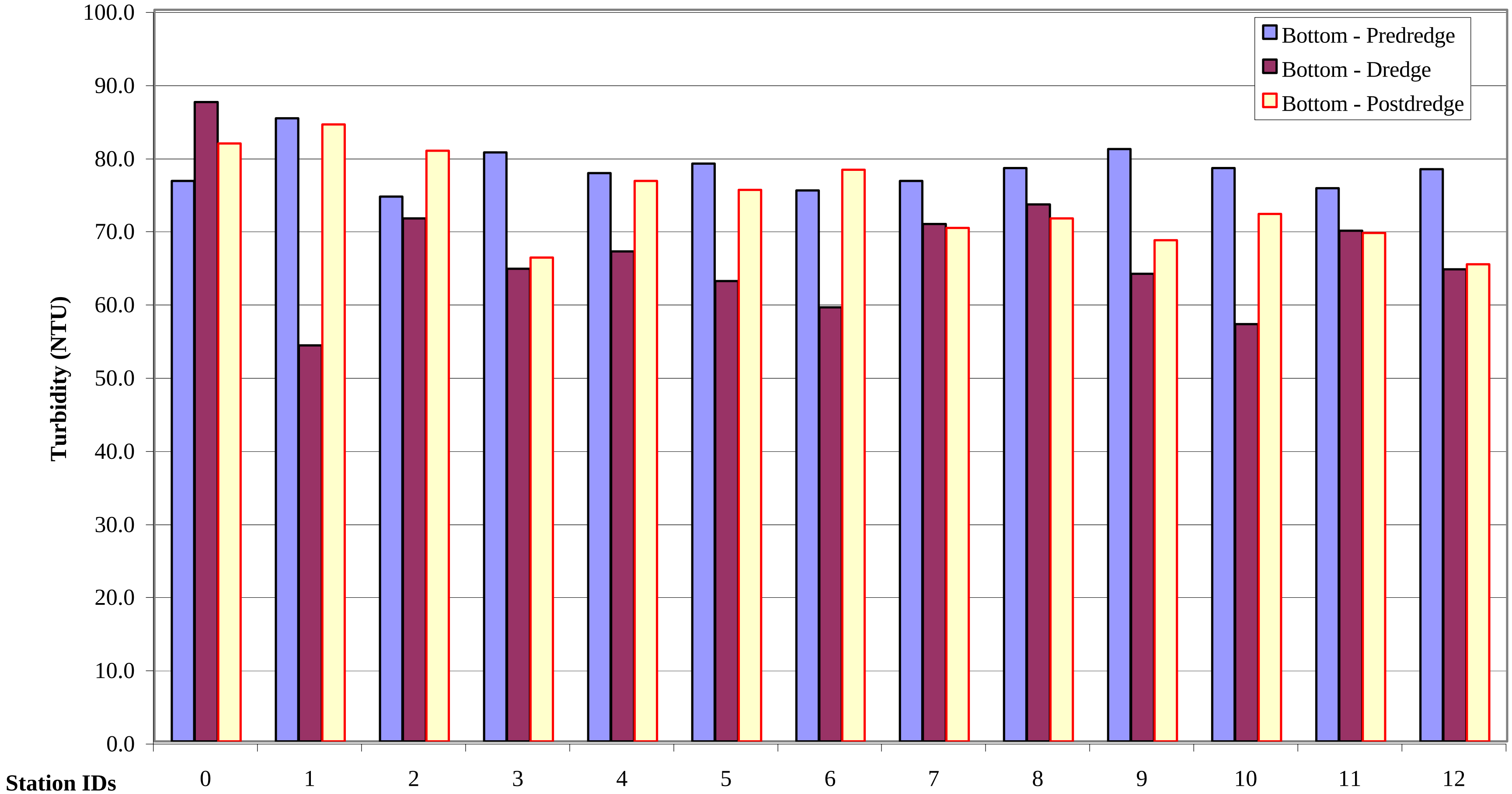
Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Figure 6-6 Field Turbidity Monitoring Data (Mid-depth Samples - May 27, 2002)



Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Figure 6-7 Field Turbidity Monitoring Data (Bottom Samples - May 27, 2002)



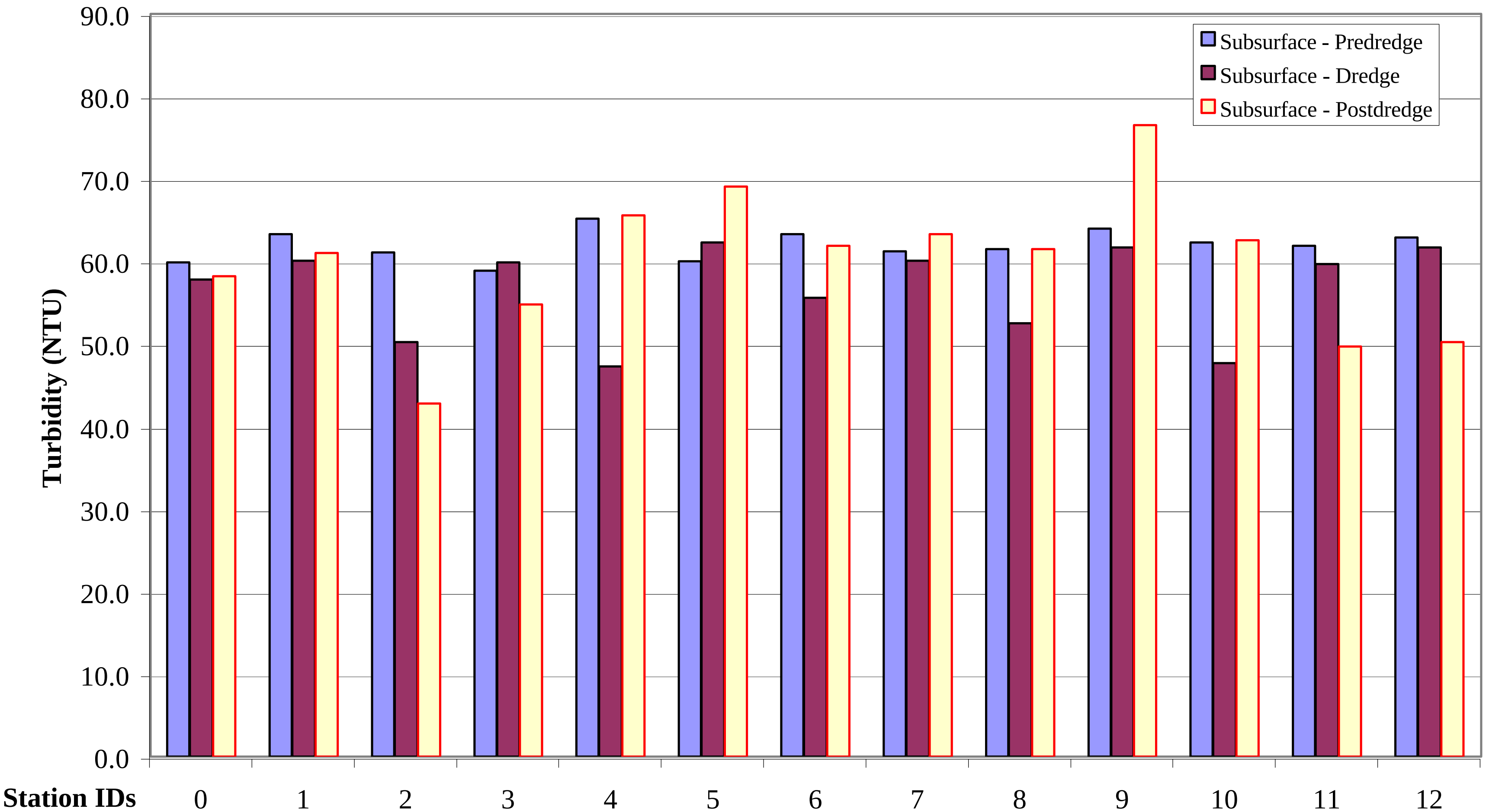
Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Table 6-11 Field Turbidity Monitoring Data (May 28, 2002)

Station ID	Round 1 (Pre Dredging) Start Time = 0655, Finish Time =0810 *Wave Height =1/2' - 1'* *Wind Direction = ENE*			Round 2 (Active Dredging) Start Time = 1245, Finish Time =1410 *Wave Height =2' - 4'* *Wind Direction = ENE*			Round 3 (Post Dredging) Start Time = 1700, Finish Time = 1810 *Wave Height = 2' -3'* *Wind Direction = ENE*		
	Subsurface - Predredge	**Middepth - Predredge**	**Bottom - Predredge**	**Subsurface - Dredge**	**Middepth - Dredge**	**Bottom - Dredge**	**Subsurface - Postdredge**	**Middepth - Postdredge**	**Bottom - Postdredge**
0	59.9	67.9	71.8	57.8	64.7	65.9	58.2	66.1	62.9
1	63.3	62.2	61.8	60.1	64.1	66.6	61.0	55.7	68.5
2	61.1	64.3	66.5	50.2	65.7	61.0	42.8	65.0	65.4
3	58.9	67.0	62.6	59.9	63.0	60.1	54.8	66.5	67.2
4	65.2	64.1	63.9	47.3	65.0	49.3	65.6	56.1	68.7
5	60.0	66.5	63.4	62.3	59.8	60.0	69.1	59.5	71.2
6	63.3	67.9	69.4	55.6	61.2	60.4	61.9	60.2	65.1
7	61.2	66.3	61.9	60.1	56.9	61.7	63.3	60.2	66.7
8	61.5	64.8	66.2	52.5	64.9	59.0	61.5	61.9	65.5
9	64.0	71.1	73.0	61.7	61.8	63.8	76.5	71.2	78.5
10	62.3	71.6	65.8	47.7	47.0	45.3	62.6	66.7	64.0
11	61.9	61.0	65.4	59.7	57.8	58.9	49.7	58.9	64.2
12	62.9	64.9	64.1	61.7	58.7	65.8	50.2	47.4	59.2

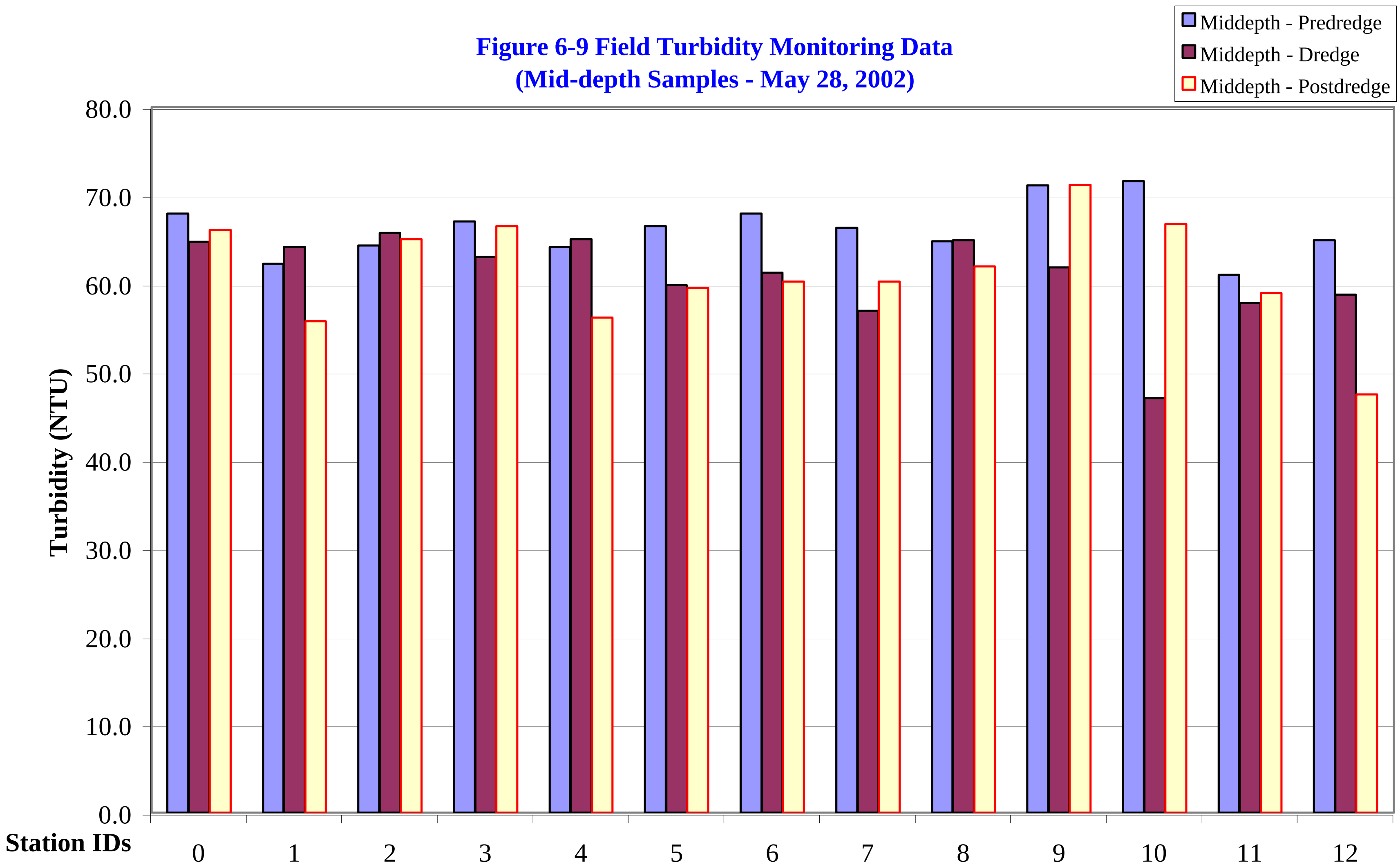
Notes:
1. All readings are in NTU
2. Station ID 0 indicates location adjacent to the dredge head;
3. Stations 1 - 6 were located along a transect following the prevailing wind direction (Station 1- upwind location, Station 6 downwind location).
4. Stations 7-12 were located along a transect that ran perpendicular to the above transect.

Figure 6-8 Field Turbidity Monitoring Data
(Subsurface Samples - May 28, 2002)



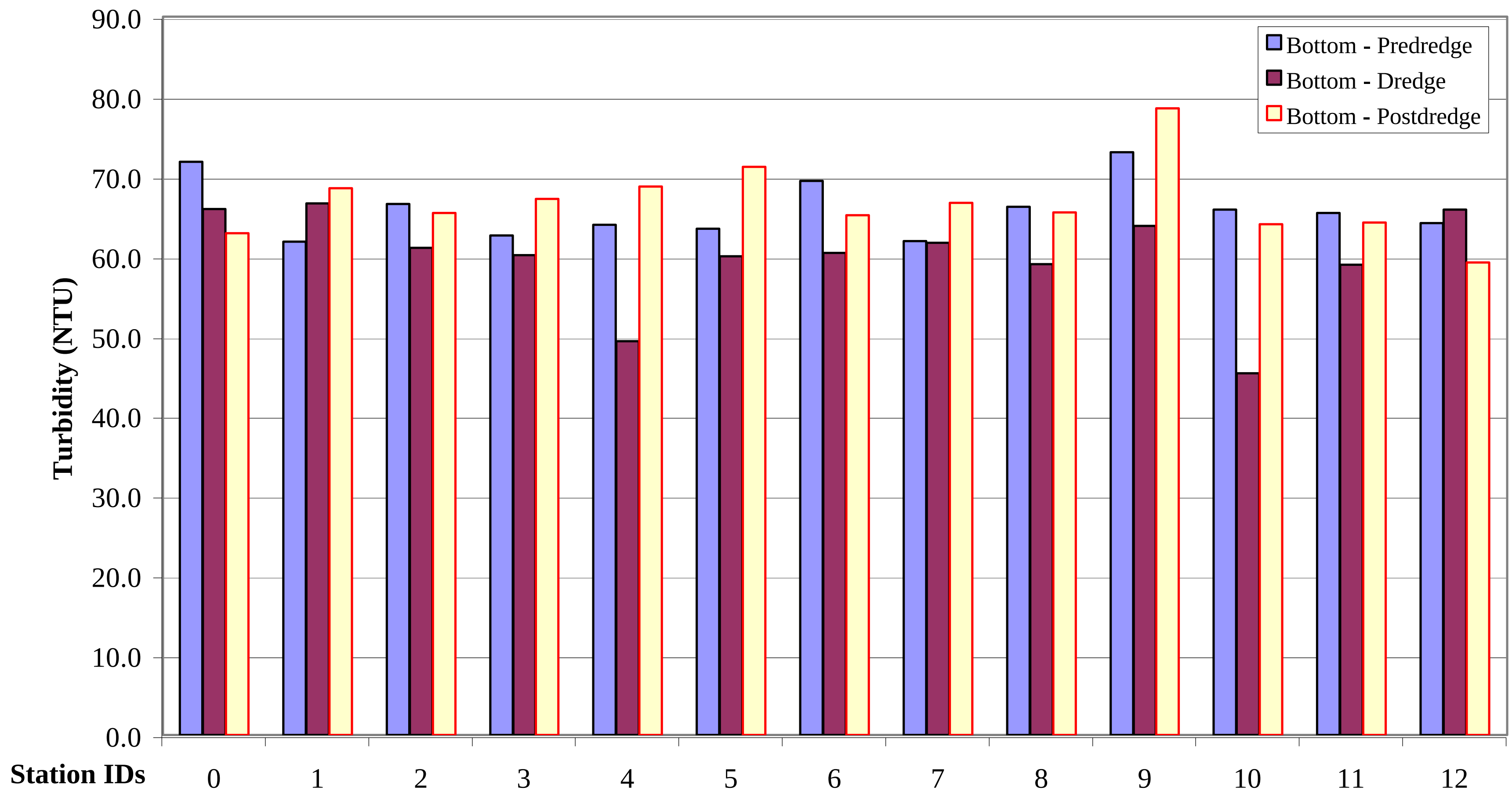
Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Figure 6-9 Field Turbidity Monitoring Data (Mid-depth Samples - May 28, 2002)



Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Figure 6-10 Field Turbidity Monitoring Data (Bottom Samples - May 28, 2002)



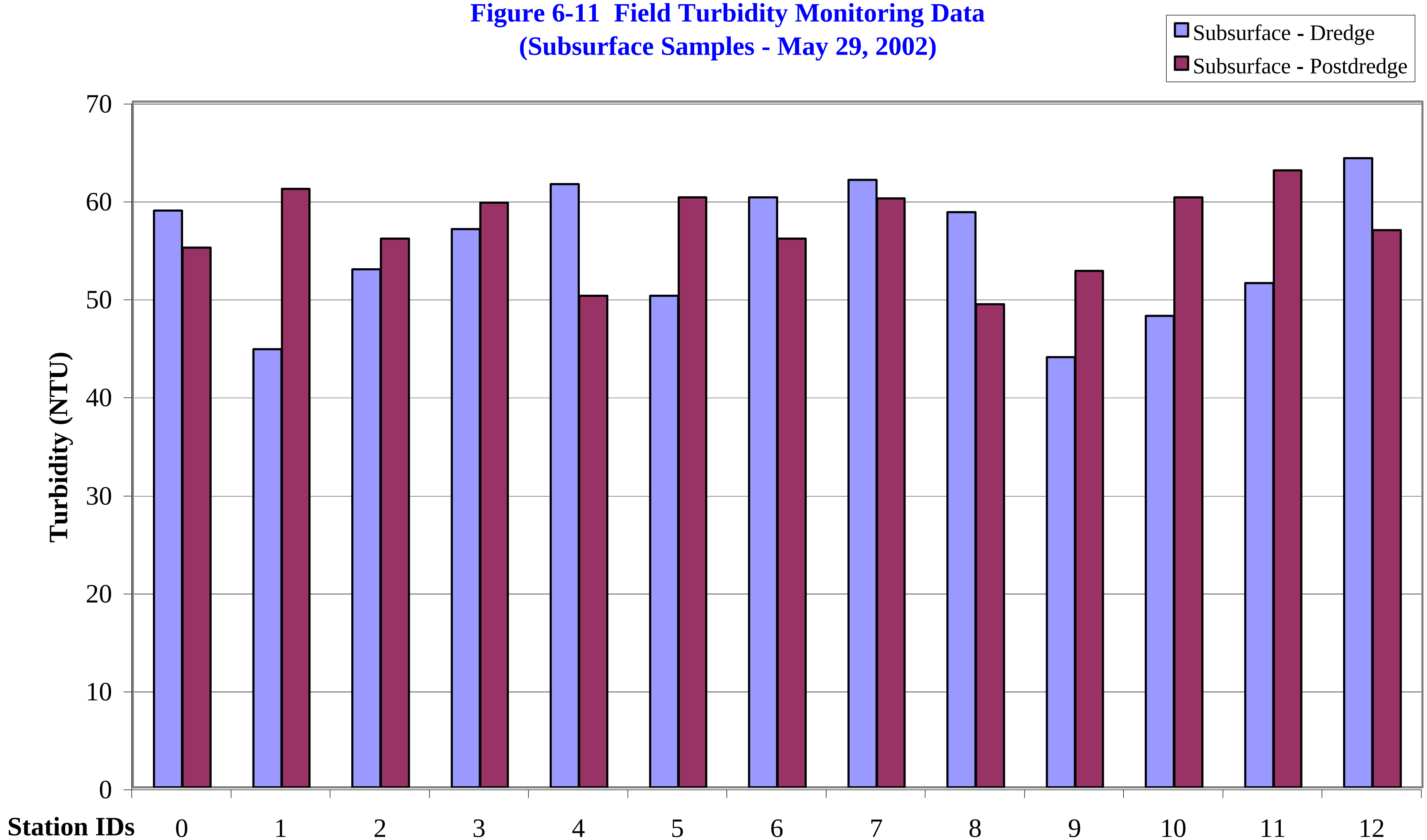
Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Table 6-12 Field Turbidity Monitoring Data (May 29, 2002)

Station ID	Round 1**			Round 2			Round 3		
	Start Time = , Finish Time =			Start Time = 1140, Finish Time = 1305			Start Time = 1715, Finish Time = 1820		
	Wave Height =			*Wave Height = <1/2'*			*Wave Height = <1/2'*		
	Wind Direction =			*Wind Direction =NE*			*Wind Direction =NE*		
	Subsurface - Predredge	Middepth - Predredge	Bottom - Predredge	Subsurface - Dredge	Middepth - Dredge	Bottom - Dredge	Subsurface - Postdredge	Middepth - Postdredge	Bottom - Postdredge
0	--	--	--	58.9	61.7	65.6	55.1	57.2	56.9
1	--	--	--	44.7	56.7	60.5	61.1	55.4	52.2
2	--	--	--	52.9	59.6	63.5	56.0	42.3	57.8
3	--	--	--	57.0	56.4	60.8	59.7	53.0	60.2
4	--	--	--	61.6	52.6	62.3	50.2	43.7	58.6
5	--	--	--	50.2	53.4	58.9	60.2	62.0	59.6
6	--	--	--	60.2	58.8	65.1	56.0	52.9	58.9
7	--	--	--	62.0	55.4	64.1	60.1	48.0	54.5
8	--	--	--	58.7	61.3	60.9	49.3	41.8	50.0
9	--	--	--	43.9	55.5	64.2	52.7	46.6	55.3
10	--	--	--	48.1	55.7	70.6	60.2	58.8	64.5
11	--	--	--	51.5	49.8	60.3	63.0	60.5	66.7
12	--	--	--	64.2	61.0	62.3	56.9	53.8	52.8

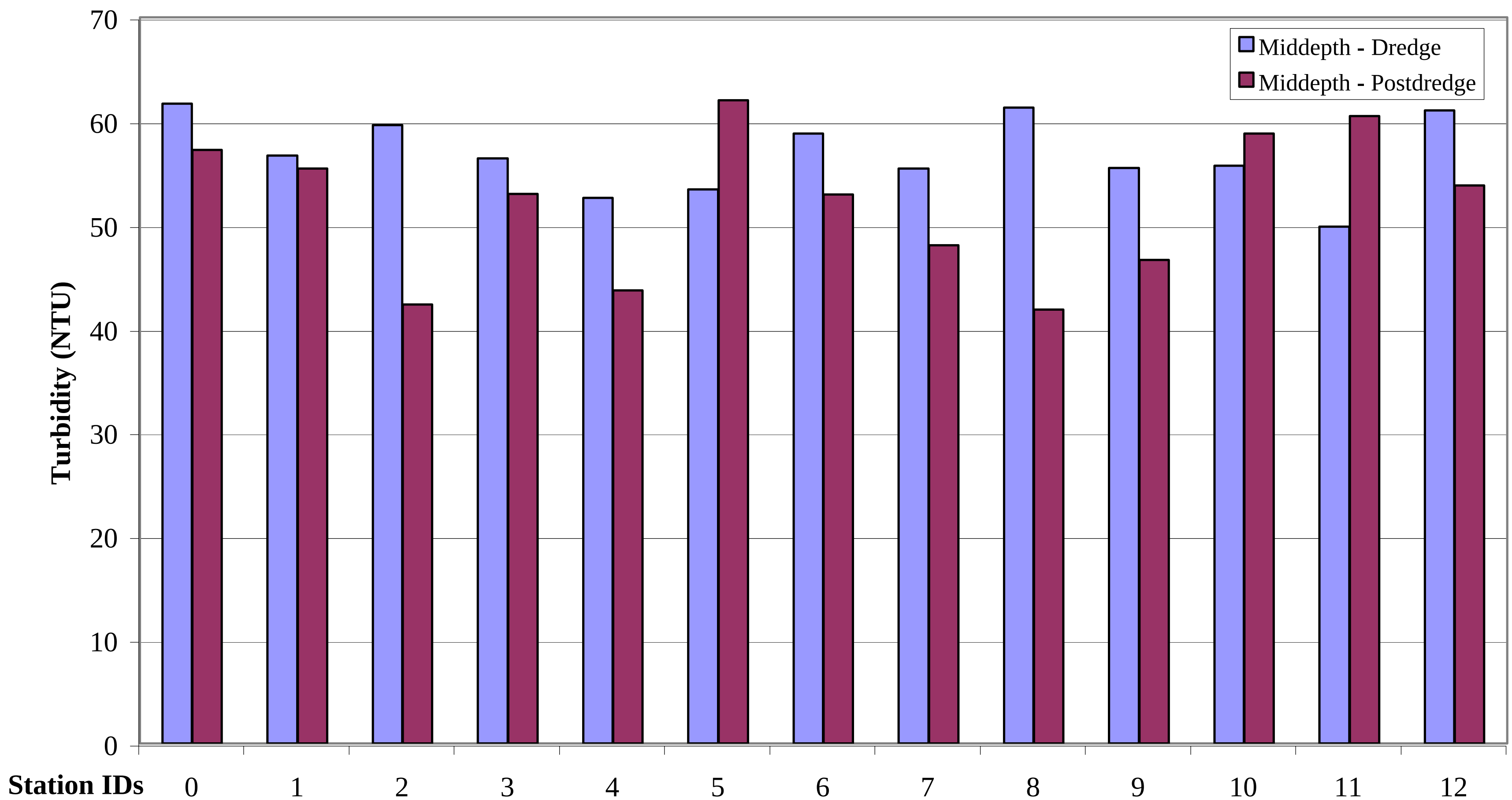
Notes:
1. All readings are in NTU
2. Station ID 0 indicates location adjacent to the dredge head;
3. Stations 1 - 6 were located along a transect following the prevailing wind direction (Station 1- upwind location, Station 6 downwind location).
4. Stations 7-12 were located along a transect that ran perpendicular to the above transect.
5. ** No data collected due to equipment malfunction.

Figure 6-11 Field Turbidity Monitoring Data (Subsurface Samples - May 29, 2002)



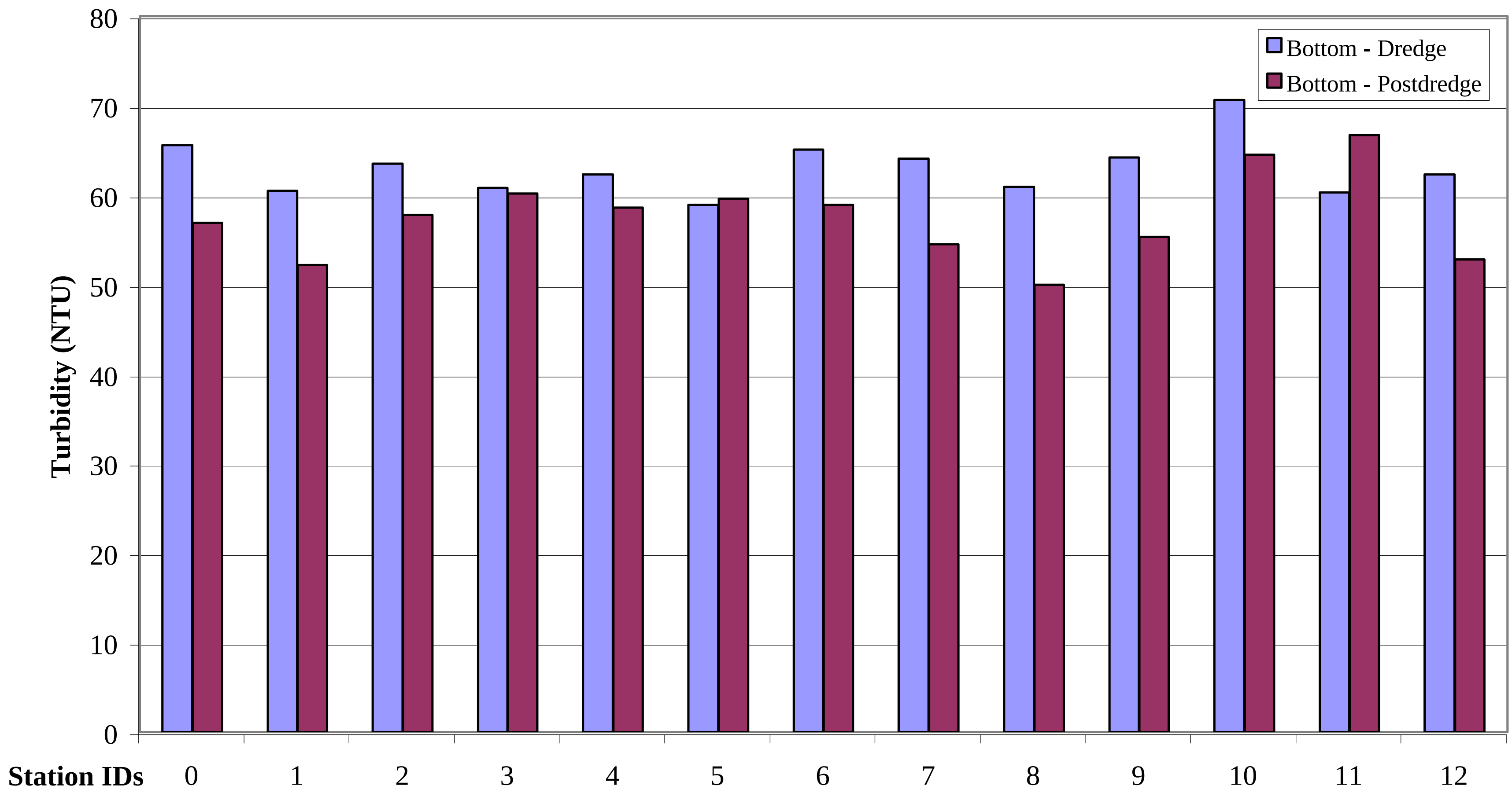
Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Figure 6-12 Field Turbidity Monitoring Data
(Mid-depth Samples - May 29, 2002)



Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Figure 6-13 Field Turbidity Monitoring Data
(Bottom Samples - May 29, 2002)



Station 0 was close to the dredge head.
Station 1 was the upwind location; Stations 2 to 6 followed the wind direction.
Stations 7 to 12 were located on a transect parallel to the transect that tracked the wind direction.

Table 6-13 PWTS Water Quality Monitoring Data (May 30, 2002)

Parameters	Units	Station ID		Field Duplicate[1]
		Influent	Effluent	
Alkalinity	mg/l	118	90	94
TOC	mg/l	21.2	17.8	18.1
Fecal Coliforms	MPN/100ml	<2 IQ	<2 IQ	<2 Q
Hardness	mg/l	188	180	172
Ammonia (dissolved)	mg/l	0.055	0.052	0.045
TKN	mg/l	1.60	1.00	1.58
$NO_2 + NO_3$	mg/l	0.779	0.754	0.744
$NO_2 + NO_3$ (dissolved)	mg/l	0.945	0.874	0.896
Total Phosphorus	mg/l	NR	NR	NR
Dissolved Phosphorus	mg/l	0.191	0.140	0.140

Notes

[1]Field duplicate was collected from effluent sample

I = Result between detection limit and practical quantitation limit.

Q = Result analyzed out of holding time.

Data from:
WATER-530-01
WATER-530-02
DUP-1

Table 6-14 PWTS Water Quality Monitoring Data (May 31, 2002)

Parameters	Units	Station ID		Field Duplicate[1]
		Influent	Effluent	
Alkalinity	mg/l	122	98	120
TOC	mg/l	20.8	18.2	20.9
Fecal Coliforms	MPN/100ml	<2 Q	<2 Q	<2 Q
Hardness	mg/l	184	176	172
Ammonia (dissolved)	mg/l	0.936	0.956	0.920
TKN	mg/l	2.07	2.12	2.09
$NO_2 + NO_3$	mg/l	0.049	0.047	0.049
$NO_2 + NO_3$ (dissolved)	mg/l	0.116	0.090	0.119
Total Phosphorus	mg/l	NR	NR	NR
Dissolved Phosphorus	mg/l	0.074	0.010 I	0.077

Notes

[1]Field duplicate was collected from influent sample

NR = Analysis not required.

I = Result between detection limit and practical quantitation limit.

Q = Result analyzed out of holding time.

Data from:
WATER-531-01
WATER-531-04
DUP-2

Table 6-15 PWTS Water Quality Monitoring Data (June 1, 2002)

Parameters	Units	Station ID		
		Influent	Effluent	Field Duplicate[1]
Alkalinity	mg/l	119	<1.0	117
TOC	mg/l	22.2	6.97	21.7
Fecal Coliforms	MPN/100ml	<2 Q	<2 Q	<2 Q
Hardness	mg/l	184	180	164
Ammonia (dissolved)	mg/l	0.076	0.239	0.070
TKN	mg/l	1.35	0.58	1.28
$NO_2 + NO_3$	mg/l	0.581	0.443	0.410
$NO_2 + NO_3$ (dissolved)	mg/l	0.500	0.426	0.474
Total Phosphorus	mg/l	NR	NR	NR
Dissolved Phosphorus	mg/l	0.031	<0.004	0.032

Notes

[1]Field duplicate was collected from effluent sample

NR = Analysis not required.

Q = Result analyzed out of holding time.

Data from:
WATER-61-02
WATER-61-03
DUP-3

Table 6-16 PWTS Water Quality Monitoring Data (June 2, 2002)

Parameters	Units	Station ID		
		Influent	Effluent	Field Duplicate[1]
Alkalinity	mg/l	117	<1.0	122
TOC	mg/l	20.6	6.90	21.7
Fecal Coliforms	MPN/100ml	<2 Q	<2 Q	<2 Q
Hardness	mg/l	184	192	188
Ammonia (dissolved)	mg/l	0.042	0.090	0.052
TKN	mg/l	1.24	0.31 I	1.23
$NO_2 + NO_3$	mg/l	0.571	0.598	0.579
$NO_2 + NO_3$ (dissolved)	mg/l	0.617	0.604	0.578
Total Phosphorus	mg/l	NR	NR	NR
Dissolved Phosphorus	mg/l	0.066	<0.004	0.062

Notes

[1]Field duplicate was collected from influent sample

NR = Analysis not required.

I = Result between detection limit and practical quantitation limit.

Q = Result analyzed out of holding time.

Data from:
WATER-62-03
WATER-62-04
DUP-4

6.2 HYDROGRAPHIC SURVEYS

The objective of the hydrographic surveys was to collect and interpret bathymetric data from the Pilot Dredging Site (PDS). Bathymetric data was collected before, during, immediately after, and approximately two weeks after pilot dredging was conducted. Comparison of data collected before dredging began (pre-dredging survey), during dredging (progress survey), and after dredging (after-dredging survey) was used to determine changes in bathymetry associated with the dredging. Data collected several days after the dredging has been completed (follow-up survey) was compared to the after-dredging survey data to determine if and how rapidly the dredged area refilled with fluid muds from the surrounding area.

Bathymetric surveys were conducted by Arc Surveying and Mapping, Inc. of Jacksonville, Florida under supervision of Case O'Bourke Engineering, Inc. of Miami, Florida.

6.2.1 Survey Methodology

Bathymetric surveys were conducted using the **Reson 8124 SeaBat** multi-beam depth sounder and a **Knudsen 320M** dual-frequency depth sounder. Use of dual frequency and multi-beam technology was chosen to allow independent determination of the vertical boundary of the fluid mud layer. Frequencies of 200 kHz were used to establish the top of the fluid mud layer. The lower layer was delineated using acoustic frequencies in the 20 to 30 kHz range.

Horizontal and vertical controls for the project were established from US Army Corps of Engineers (USACE) monuments at Port Mayaca (FCE 3838, Elevation 39.91 NGVD 29) and Canal Point (PB-CAN-RM1, Elevation 34.58 NGVD 29). Horizontal datum is NAD83, Florida East Zone.

Survey Frequency - Four (4) sets of surveys were conducted.

- A **pre–dredge** survey was conducted on May 7, 2002. Data from this pre-dredge survey was used to establish baseline conditions.

- A **progress survey** was conducted on May 25, 2002 within 24 hours after dredging was temporarily suspended. Data from the progress survey was used to determine the accuracy of the dredging equipment to efficiently excavate the fluid mud layer and to ascertain the smoothness of the dredge cut including the development of windrows and pot-holing.

- A **post-dredging survey** was conducted on May 31, 2002, 24 hours after completion of the field demonstration dredging. Data from the post-dredging surveys was used to determine the amount and degree of completeness of the removal of the excavated fluid mud layer.

- A **follow-up** survey was conducted on June 13, 2002, 13 days after completion of dredging to track temporal changes in the substrate following completion of dredging. Data from the follow-up survey was compared to pre-dredge and post-dredge survey data to determine the magnitude at which fluid muds migrate into the dredged area from outside of the PDS.

Prior to the start of the pre-dredge survey, a **control survey** was conducted on April 24, 2002 to establish horizontal and vertical controls around the PDS. These controls served as baseline throughout the duration of the project. The control survey efforts were not intended to collect bathymetric data, but were meant to establish references for successive work. A temporary but fixed water elevation gauge board was set up prior to the pre-dredge survey. During each survey water level changes were visually monitored using this gage.

Two surveys were run at each survey event over a 1000' X 1000' square area encompassing the PDS. Note that even though the PDS measures approximately 416' X 416' a much bigger square around the PDS was surveyed. The oversized survey area was used to determine the magnitude and direction of the flow of soft sediments returning to the dredged section, if any.

Each of the four electronic surveys was performed using differential GPS with USCG Cape Canaveral Navbeacon corrections, which provided sub-meter accuracy. A check into local control (monuments at jobsite) was performed at the start and end of each day's survey. All calibration data, i.e. latency tests etc., were recorded and reported.

At the beginning and ending of each survey the depth sounder was calibrated using a standard bar check procedures in accordance with USACE EM 1110-2-1003 standards for Class 1 Hydrographic Surveys. This procedure involves lowering a bar under the transducer at five foot increments to adjust the surveying systems for the speed of sound in the water column. Bar check calibration was confirmed by a water velocity profiler, which was lowered into the water column and recorded the speed of sound at various depths. The survey fathometer was calibrated with this data.

Equipment calibrations were recorded on the data scroll with a continuous graph of 200 kHz and 28 kHz soundings in addition to the digital recording of the date of survey, time of day, and x and y coordinates for the location of each sounding. Data processing was accomplished using Coastal Oceanographic Hypack software. This software is standard among most USACE districts and is used worldwide.

Multi-Beam Surveys – were conducted with a 25'-30' line spacing to determine the fluid mud layer. This line spacing allowed an overlap of 15 feet with each adjacent survey line and provided 100% coverage of the surveyed area. Since the multi-beam survey covers 100% of the surveyed bottom,, it eliminates the interpolation of data between transects. The multi-beam survey is designed to indicate the top of the sediments rather than attempt to penetrate the soft sediments.

The multi-beam survey was tuned on the pre-dredge survey to attempt to discern the top of the lighter mud versus the top of the heavier mud. It was expected that by reading the first signal returns (minimum returns) within each pulse that the average top of the lighter mud layer would be discerned. Also, by reading the last signal returns (maximum returns) within each pulse that the average maximum depth computed would signify the top of the heavier mud. The examination of results discarded this idea and subsequent surveys were not tuned to differentiate these differences.

Multi-beam surveying was conducted using a Reson 8124 SeaBat depth sounder, operating at 200kHz. The high frequency pulses were used to record the top of the mud layer. All surveys data were recorded digitally and on a fathometer scroll.

Dual Frequency Surveys – were conducted with a line spacing (transects) of 50', covering a bottom width of 1-2 feet over the length of the survey line (note no overlap of covered areas). The high frequency part of this transducer is similar to the transducer frequency used in the multi-beam survey and was used to verify its first echo returned (top of fluid mud layer) against the return found in the multi-beam survey. The first echo returned was the signal received by the high frequency transducer of the first abrupt density shift in the water column, indicating the probable top of the fluid mud layer. Simultaneously with the use of the high frequency transducer, the low frequency transducer penetrated the soft sediments and attempted to detect the second abrupt density shift, indicating a harder substrate. Minimal excavation of the hard bottom was expected, therefore the need to survey 100% of the area was eliminated, a reduced coverage using transects was proposed, and the above line spacing was selected.

Dual frequency surveying was conducted using a Knudsen 320M dual frequency depth sounder, operating simultaneously at 200kHz and 28 kHz. The higher frequency pulses were used to record the top of mud layer; the lower frequencies were used to determine the bottom of the mud layer. All surveys data were recorded digitally and on a fathometer scroll.

6.2.2 Observations From Bathymetric Surveys

The overall depth of water in the Lake Okeechobee Pilot Dredging Site is relatively shallow, namely, 12 to 14 feet. The general bathymetry of the site shows that the area is very flat with no substantial changes in depth and no real slope to the surface area of the sediments. The expected depth of face of the soft muddy material was approximately 30 cm (14-15 in). Changes in the bottom depths after dredging were therefore expected to be no greater than the depth of face of the anticipated soft mud material.

Very minimal, or no removal of the harder substrate was expected. Volumes were to be computed to determine the overall amount of soft sediments removed and to determine if any harder substrate was removed. Volumes were also to be used to determine if any sloughing-in of material from other areas occurred. The thin depth of face of material to be removed necessitated greater accuracy requirements in volume computations. By using the multi-beam's 100% coverage, which eliminated the interpolation of data between transects, it allowed better accuracy in volume computations.

GPS positional accuracy of 1-2 feet was achieved and was greater than the sub-meter accuracy required. Vertical accuracy of fathometer readings is a function of the fathometer used, the water depth surveyed, and must be corrected for vessel movements. The vessel employed utilized heave compensation that adjusted, real-time, for vertical, rotational, pitch, and yaw movements of the vessel. Vertical accuracy was within 1 tenth of a foot the majority of the time. Survey data printouts are presented in Appendix E.

6.2.2.1 Analysis of Pre-Dredge Survey Results

The pre-dredge survey was conducted in favorable weather conditions with no equipment on site. Results of the **multi-beam** survey were analyzed to attempt to depict the zoning or layering within the soft mud layer. Based on visual observations of the core samples taken at the site previously, it was anticipated that there was a layer of very soft mud atop the denser layer of mud. A firmer substrate was expected below the denser mud layer.

Cross-sections of the pre-dredge survey output (Appendix E) depict an upper line, which is the average reading of the "minimum" returns within the zone of influence of the multi-beam transducer (Appendix E). The next line depicts the "maximum" returns found within the same zone of influence of the same transducer. The "tuning" of the multi-beam signatures was used to attempt to delineate the limits of the very soft mud layer. The results can only show the changes in density detected by the transducer.

The results of this survey are inconclusive as to whether the top line and the second line signatures truly represent the limits of the very soft mud layer; therefore, the results of the multi-beam survey minimums and maximums can only be interpreted to merely define the "range" in depths that the multi-beam signature was reflected. It is possible that the signatures are attempting to show the upper and lower boundaries of the very soft mud, but this conclusion cannot be confirmed.

The **dual frequency** survey data shows two distinct returns. The upper line is the top of soft sediment and the lower line is the firmer substrate. In this case, the upper line (200 khz) matches the second return from the multi-beam survey, thus verifying the accuracy and repeatability of the system used. Cross-sections of the pre-dredge dual frequency survey data show three lines:

- The top line is the "minimum" return from the multi-beam survey.
- The middle line represents two lines: the lower "maximum" return of the multi-beam survey and the high frequency (200 khz) return of the dual frequency transducer.
- The bottom line is the low frequency return of the dual frequency transducer.

The survey results indicate that the top of sediment is relatively smooth with no more than 0.5 feet difference in depth throughout the area. Some sample probes taken by the survey team during the establishment of the piling locations detected that a harder, sandier bottom existed below the softer sediments. However, they were inconclusive in verifying whether the firmer bottom was a perceptible stratification between the softer sediments and the firmer substrate.

The low frequency transducer results indicated some irregularity in the firmer bottom, possibly indicating that the harder bottom is undulating. The fluctuations could also suggest that there is a gradual shifting in material density whereby the 28 khz low frequency transducer is not fully penetrating the softer sediments before getting a return, thus fluctuating within the lower part of the softer layer above the suspected sand layer.

6.2.2.2 Comparison of Pre-Dredge & Progress Survey

The Progress Survey was conducted to provide an overview of the process and to determine if any field adjustments to the dredging process needed to be made. It was also designed to measure the amount of material and to determine if any filling of the dredge cut was occurring as the dredge progressed through the dredging area. At the start of the survey the weather was fine, but the weather quickly deteriorated and affected both the gathering of data and accuracy of the data. In addition, previous weather had forced the dredging activity to take shelter behind a ring of moored barges and thus prevented access to certain areas. Weather and moored equipment also forced an alteration to the orientation of the survey lines. This orientation did not affect the multi-beam survey since it has 100% coverage, but the dual frequency survey lines were run perpendicular to the original orientation. Therefore, the results cannot be readily compared against the pre-dredge to gauge any perceptible change in the harder substrate. The low frequency results have not been displayed on the cross-sections for that very reason. The multi-beam results are readily comparable against the pre-dredge results except for areas impacted by weather.

The southernmost quadrant of the dredging area showed some increase in overall depth, with some trenching of dredge cuts evident. Not all the material was moved and not all the area was covered. The easternmost quadrant of the area showed some concentrated dredging efforts and the trenching pattern was also exhibited. The cross-sections in undisturbed areas indicated some vertical change in depth, but due to the impacts associated with weather, no real conclusions can be drawn regarding migration of material into the site. Within the dredging limits, some changes were noted in the upper surface line showing the tracks and depth of cut of the dredge. Changes in depth varied, with up to 1 foot of material being removed in places.

Track lines for the dredge's position within the dredging area were not fully recovered from a portion of the project's operational data and therefore are shown on the plan views to the extent that data was salvageable. Cross-section lines of the progress survey reflect the elimination of the "minimum" multi-beam depth (previously shown on the pre-dredge survey sections) as being too confusing and because it was felt that it did not reflect the limits of a lighter mud zone as previously suspected and depicted on the pre-dredge survey. For comparison purposes, cross sections of the progress survey were overlaid on cross-sections of the pre-dredge survey output. Overall, the results of the progress survey are quantitatively inconclusive, but yielded some results to guide future surveying activities in the lake.

6.2.2.3 Comparison of Pre- & Post-Dredge Surveys

The post-dredge survey was conducted to provide a perspective of the overall success of the dredging activity. It was designed to measure the amount of material and to determine if any filling of the dredge cut was occurring as the dredge progressed through the dredging area. The survey data was retrieved in fair weather. Results were displayed in a similar fashion to the progress survey, with the post-dredge survey results overlaying the pre-dredge survey results. The survey reflected work that had been done to date and also reflected the progress since the progress survey.

Work since the progress survey was conducted in the upper half of the dredging area, namely the easternmost and northernmost quadrants. Efforts in this area showed that material was removed over a large portion of the area and the depth of removal of material was predominantly within the softer sediments with occasional penetrations of up to approximately 2 feet, potentially into the harder substrate. Volumes computed against the pre-dredge survey indicate that approximately 577 cubic yards of material was excavated from the area. It should be noted that due to the characteristics of the dredged sediments (low bulk density value) in-filling occurred within 24 hours, limiting the usefulness of the post dredge survey.

The survey also indicates that not all the material was removed from the areas dredged. Volumes were computed from the soft sediment line (soft mud line) exhibited on the pre-dredge and post-dredge surveys. The cross-sections show that the pre-dredge and post-dredge soft mud lines overlay relatively well, indicating that the survey repeatability is high. Cross-section views of the low frequency return show a large vertical fluctuation and a much lower degree of repeatability. The data results are explained below:

Vertical Fluctuations – The exaggerations in the plotted scales between the vertical scale and the horizontal scales used magnify the depth fluctuations to a great degree. In addition, a relatively smooth, consolidated bottom will return a smoother image than a bottom that has been dredged or otherwise disturbed. Also, once disturbed, the bottom density is lighter than reflected in the pre-dredge and the transducer signals will penetrate the lighter mud to varying degrees, adding to the fluctuations.

Repeatability – Survey repeatability is a measure of the degree to which the survey process can be duplicated over consecutive attempts, i.e. whether the vessel can traverse the exact same line and detect the exact same depth. Undisturbed areas, where often repeatability can be best measured, are normally used to analyze the degree to which the two referenced surveys are overlaid and viewed for repeatability. In a multi-beam survey in which 100% of the area is covered, horizontal position errors are reduced and therefore vertical repeatability should be a function of the calibration and accuracy of the equipment. The repeatability of the multi-beam survey was relatively high.

With the dual frequency survey run over parallel survey lines (transects), the repeatability is also a function of the accuracy of the horizontal positioning of the transducer exactly over the same point in the earlier survey. Also, the low frequency transducer penetrates the water column until a shift in density occurs that is sufficient to reflect the signal. In the above case, the low frequency transducer appears to be seeking the harder substrate, but never seems to lock on to the distinctive layer. It appears to be fluctuating within the thicker soft sediment layer. Therefore, the low frequency repeatability is relatively low.

In any survey, positioning exactly over the same point is nearly impossible. In the above survey comparison, the variability in the two surveys is more a function of positioning and the fluctuating signal return. The results of the low frequency data appear to show some very slight removal of the harder substrate material, but no firm conclusions can be drawn.

The survey of the upper surface within the undisturbed areas does not show any measurable natural movements of material within the surveyed areas. It should be noted that the post-dredge survey was taken approximately 24-36 hours after cessation of dredging. Therefore, no conclusions can be drawn on the natural shoaling, migrating or scouring of the area from wave, winds, currents, etc.

6.2.2.4 Comparison of Post-Dredge & Follow-Up Survey

The follow-up survey was taken almost two weeks after the cessation of dredging thus allowing a longer period of settling time for the suspended sediments. The results were compared against the post-dredge survey in lieu of the pre-dredge survey so as to reflect any bottom changes evident in the period after dredging.

The overall review of the follow-up survey results indicate that there is a slight decrease in bottom depths over a large area when compared against the post-dredge survey. There appears to be substantial migration of material into the area, including the undisturbed areas, since the post-dredge survey was conducted. The natural gradient or slope of the bottom is essentially zero; therefore, the in-filling that has occurred is most probably the result of weather-induced movements (wind, waves, currents, etc.) rather than slope-induced movements. While there may be some shifting and settling of material within the trenches created during the course of dredging, the predominance of material movements is from outside the surveyed area. In addition, any transport of material into the area is sufficient enough to mask any consolidation of material that may have taken place since the cessation of dredging. The magnitude of shoaling that has occurred since dredging is approximately 459 cubic yards (80% of the material previously excavated).

It is uncertain as to whether the shoaling evidenced is constant over time or if it is constant in magnitude. It is also uncertain if this magnitude of shoaling also occurred <u>during</u> dredging. This shoaling would have been evident in the variance between claimed production and surveyed production.

The result of the low frequency survey shows the same vertical fluctuations that were observed on the previous surveys. It is suggested that some vertical variations could be the result of shoaling that may have occurred between surveys. More likely, the results of the low frequency surveys were inconsistent.

6.2.3 Conclusions From Hydrographic Surveys

The results of the surveys indicate that measurements of such a small vertical face in sediments that are very soft and non-homogeneous can be extremely difficult to quantify, especially in a shallow, open lake area subject to heavy weather. While the multi-beam survey provides sufficient data to eliminate any interpolation of data that is inherent in other surveys that traditionally utilize parallel survey lines, it can be extremely expensive to conduct over very large areas. In addition, given the accuracy of the vertical measurement of 1 tenth to 2 tenths of a foot, the error introduced in measuring 1.2 ft (30 cm) of material is very significant (approximately 8-16 %). This degree of accuracy in achieving depths is normally of much less concern in projects removing larger face heights of material since it represents a much smaller percentage of the total. Similarly, if a high frequency transducer is utilized and survey lines are conducted over parallel transects, the degree of repeatability is greatly lessened by the horizontal inaccuracy of the vessel (inability to precisely traverse the exact same line). The reduction in repeatability increases the potential for additional vertical fluctuations and thus the accuracy of the quantities removed is potentially jeopardized.

The use of a low frequency transducer makes sense in determining the depth of the hard substrate. In this particular case, the 28khz transducer appeared to be incapable of defining any stratification of the sediments that would suggest that the hard substrate was a relatively smooth surface. This could be the result of a relatively smooth transition between the density of the softer sediments and the harder substrate whereby the abrupt change in density is not discernible. Conversely, it could be a result of not having sufficient transducer power to fully penetrate the softer layer and define the harder substrate surface, if one exists at all.

Consideration should be given to conducting a brief on-site test of the 28 khz transducer against a "sub-bottom profiler", which uses a lower frequency, more powerful transducer, to attempt to delineate the hard substrate. A short test of less than 1 day would allow a comparison of the bottom signatures of both systems in defining if any stratification of the sub-bottom firm substrate material exists below the softer mud layer.

The dual frequency transducer system used is a common system that can be used by most trained personnel. The sub-bottom profiler is a more complex, and expensive system that requires more sophisticated training and is less common. In addition, the sub-bottom profiler is a single transducer system that cannot be used simultaneously with the high frequency transducer. Hence, it would require double surveys to obtain the same results. Emphasis must be given to the necessity of having to conduct before and after surveys with the low frequency transducer (or the sub-bottom profiler). If volume changes in the hard substrate are not significant then either transducer can be used to give an indication of the depth of the harder substrate and thus the thickness of the soft mud.

In reviewing the post dredging surveys, it is apparent that some relatively heavy shoaling has occurred since dredging was completed. This shoaling is small in height but is expansive in area. It cannot be concluded with any certainty as to the constant nature of the magnitude of the shoaling. In the course of execution of any larger lake project, consideration must be given to the shifting of the soft sediments that will likely be occurring during the course of dredging. In other words, areas dredged may not be 100 % cleaned of any soft sediment since some lateral transport of material will likely be taking place, especially over longer periods of dredging activity.

6.2.4 Recommendations For Large-Scale Surveying

The following recommendations are made for the survey methods and equipment to be used in a much larger Lake Okeechobee project:

Prior To Initiation Of Lake-Wide Surveying

- It is recommended that a short test be conducted on-site to determine if a low frequency transducer or a sub-bottom profiler will meet project needs in defining the firmer substrate. The test should be conducted to ascertain if any layering of the substrate could be detected. If no layering is found, then a low frequency survey will not be of measurable use.

During Lake-Wide Surveying

- If the low frequency test indicates that a firm substrate is detectable, conduct a dual frequency “before removal “survey (or two surveys using a high frequency transducer and a sub-bottom profiler) on a line spacing (transects) to suit the project size. On small areas where volumes are important, line spacing of 100 feet is suggested. On larger areas, or where volume computation is less significant, use of line spacing of 250 – 500 feet or more is recommended.
- Use the low frequency output from the before removal survey to ascertain the thickness of the mud layer for project planning purposes.
- Conduct a single frequency ´”after removal” survey using the high frequency transducer on the same line spacing as the “before removal “ survey.

- Compute volume changes on only the upper, soft sediment (mud) line between the before and after surveys. Volumes should not be used for payment purposes unless recognition of the significance of the vertical error is considered.
- Measure the high frequency results from the after removal survey against the before removal survey to generate volumes removed and to gauge the relative percentage of penetration into the firmer substrate.
- Contract provisions should be evaluated to recognize the impacts that shoaling may have on any volumes that are computed by survey methods. Even a small amount of vertical change from shoaling can have an appreciable impact on surveyed volumes.

7.0 DESIGN, CONSTRUCTION, AND OPERATION OF THE CONFINED DISPOSAL FACILITY

The purpose of the CDF was to provide an environmentally protected, temporary storage area for sediments after they were dredged from the lake bottom. After being deposited into the CDF, the dredged material was allowed to settle for 24-48 hours. Upon settling, a portion of the supernatant liquid was skimmed from the top of the CDF and fed into the PWTS for treatment to remove phosphorus.

7.1 TOPOGRAPHIC SURVEY

A topographic survey was conducted to delineate the topography of the area selected for construction of the CDF. This information was subsequently used to define the roadway, roadway embankment, and the footprint of the proposed facility.

The survey was performed by Mixon Land Surveying of Jupiter, FL on February 23, 2001. The vertical datum was National Geodetic Vertical Datum (NGVD) 1929, and the reference benchmark for the survey was the South Florida Water Management disk set in concrete, stamped "B.M. S-153 1995." Its published elevation was 32.65 ft NGVD. The baseline topography was generated from a series of cross-sections taken across the roadway, down the embankment, and to the edge of the canal. Information obtained from the topographic survey is included in the final engineering drawings for the CDF[1].

7.2 SUBSURFACE INVESTIGATIONS

This investigation was necessary to identify the nature of the subsurface soils to evaluate their use in the construction of the CDF dikes. Two test pits were dug in November 2001 by Trident Tech Services in the selected CDF area. Pocket penetrometer and toro vane tests were performed in the field. A grain size analysis, a percent organic content, and proctor tests were performed in the laboratory on grab samples collected from the test pit.

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[1] *Lake Okeechobee Pilot Dredging Project – Engineering & Design Report* (EA, 2002).

The investigation identified a fine sand layer at the ground surface with some rock fragments and little silt and clay. The sand layer was approximately 3.5 ft [1.1m] thick. Beneath the sand layer, a 6 in [15 cm] muck layer was identified, which consisted primarily of dark brown fine sand with organics. Gray silty sand was identified beneath the muck layer, which appeared to continue beyond the bottom of the test pits at approximately 7 ft [2.2 m] below ground surface (bgs). The groundwater table was encountered at approximately 6 ft bgs.

7.3 DESIGN BASIS

The CDF was designed in accordance with the guidelines for minor impoundments established by the District (SFWMD 2000a). Primary considerations associated with the CDF design included:

- **Holding Capacity** – The CDF was designed to hold up to 6,000 cubic yards [4,600 cubic meters) of dredged material with a 2 ft [61 cm] of freeboard as required by the District guidance on construction of minor impoundments (SFWMD 2000a).

- **Dike Stability** – The perimeter dikes were constructed of native materials obtained from excavating the inside of the CDF and a selected area adjacent to the CDF. The slopes of the dikes were based on the results of a previously conducted slope stability analysis which had shown that internal and external slopes of 2H:1V (i.e., a 2 to 1 horizontal/vertical ratio) would provide adequate safety factor (>1.3), as recommended by COE Guidelines (COE, 1987).

- **Synthetic Liner** – The CDF was completely lined with a high-density polyethylene (HDPE) liner to ensure that materials stored inside would not leach into the groundwater. The liner was laid down in panels, which were then welded together by double wedge seams. Destructive and non-destructive tests performed on the seams verified their integrity.

- **Soil Erosion and Control** – Since the entire CDF footprint was cleared of grass and brush at the beginning of construction, the exposed area was very susceptible to erosion. The following soil erosion control measures were implemented at the site to ensure that soils did not leave the area:

1. A silt fence was placed along the entire length of the site by the canal to trap sediment in the runoff before it reached the St. Lucie Canal.
2. A grass and brush buffer was left intact along the canal to provide natural sediment control.
3. After construction of the CDF, the dikes and other disturbed areas were seeded to provide grass coverage to minimize erosion.

The CDF dikes were inspected after every rainfall event and the areas showing erosion were appropriately fixed.

7.4 CONSTRUCTION

The CDF was constructed by Rockett Environmental Services Inc. (RESI) of Deerfield Beach, FL under a subcontract to EA, in accordance with the final drawings that were approved by the District. Construction began on March 14, 2002. Significant steps in the construction process included:

1. A silt fence was installed around the delineated footprint and the area was cleared of vegetation and scrub.
2. The excavation of the two CDF cells was then initiated.
3. Excavated material was placed around the excavations and compacted to construct the dikes.
4. Additional material was removed from an adjacent borrow pit to complete construction of the dikes.
5. Soil compaction tests were conducted.
6. Once the dikes were completed, the HDPE liner was deployed and seamed over the interior of the CDF. Liner deployment took approximately one week and was completed on April 8, 2002. Destructive and non-destructive seam tests were conducted on the liner.
7. Disturbed areas were seeded and maintained as required by the erosion-control plan.
8. A chain-link fence was installed around the perimeter of the site.
9. As-built drawings were prepared and the *ERP As-Built Certification by a Registered Professional* form was completed and submitted to the FDEP on April 23, 2002 to document the final, as-built condition of the CDF.
10. Following an inspection by FDEP personnel, approval to start using the CDF was received on May 8, 2002.

As required by the work plan, weekly construction progress reports were prepared and submitted to the District. Site photos were used to document weekly progress during the construction of the CDF. Additional details on the design and construction of the CDF were presented in the report entitled *Lake Okeechobee Pilot Dredging Project – Engineering & Design Report* (EA, 2002c).

7.5 OPERATION OF THE CDF

The purpose of the CDF was to provide a temporary upland storage area for the dredge slurry, prior to final disposal or re-use as determined by the District. The CDF was constructed with two equally sized holding ponds (east and west), each capable of holding up to 3,000 yd^3 [2,300 m^3] (approximately 600,000 gallons[2.3 million liters]). The ponds were designed to provide a settling system for the dredge slurry that would promote natural water and solids separation from the dredge slurry. Both ponds were also lined with a 40 ml HDPE liner to comply with the FDEP requirements for this project, and to ensure that all material generated from the dredging operations would remain on site until final disposition was determined by the District.

Once the cargo barge was filled to the allowable maximum draft, dredging operations were halted and the cargo barge was pushed to the CDF shoreline transfer area located directly offshore from the western pond. A 6 ft [1.8 m] draft was determined in the field to be the maximum draft allowable for safe passage through the Port Mayaca channel. A 6 in [15 cm] hydraulic pump, identical to the pump used in the dredging operations, was used to transfer the dredge slurry from each of the six storage chambers used on the cargo barge to the holding ponds. A 90 ft [27.4 m] boom truck was used to lift the hydraulic pump into each of the chambers and to guide the discharge hose to the appropriate holding pond. To minimize the amount of sediment accumulation in each of the storage chambers, the transfer pump was outfitted with a slurry gate to agitate and resuspend the dredge slurry prior to discharge to the holding pond. This procedure reduced the volume of material in each chamber to less than 1 ft [30 cm] (see Table 5-3) for cargo-barge pumping data.

The western pond was used as the primary holding area for the dredge slurry and served as the chemical water-treatment feed source. The eastern pond was used as a secondary storage area for the dredge slurry and the served as the primary storage area for the effluent generated during chemical treatment. Parameters monitored at the CDF included water quality of the supernatant, which was fed into the water treatment system. Results from this monitoring are presented in

Chapter 6 (Tables 6-13 to 6-16). No other data was collected at the CDF during the course of the project.

7.6 CDF MAINTENANCE AND CLOSURE

The FDEP Permit requires that following evaporation of the supernatant, the sediments in the CDF be tested and a sediment disposal plan be submitted to the FDEP. Upon approval, the sediments are to be disposed of according to the submitted plan. Following the disposal of the sediments, the CDF will be dismantled and the site will be appropriately restored.

8.0 DESIGN, CONSTRUCTION, AND OPERATION OF THE PILOT WATER TREATMENT SYSTEM

The primary objective of the pilot water treatment process was to evaluate the effectiveness of alternative water treatment technologies for the removal of total phosphorus (TP) from the supernatant of Lake Okeechobee dredged sediments. The target TP concentration of the supernatant after treatment was less than or equal to 40 µg/L.

Bench-scale studies conducted previously had evaluated pros and cons of several alternate water treatment technologies for reducing phosphorus concentrations. Options evaluated included use of alum and ferric salts as precipitating agents, both of which have been previously shown to be effective in reducing total phosphorus concentrations to below 40 ug/L[1]. Ferric chloride was selected for the field demonstration. Alum was not considered due to the potential for bio toxicity. The scope of work for the water treatment task was to consider the potential for discharging/returning the treated effluent back to the lake. Use of alum could potentially jeopardize this effluent disposal alternative.

8.1 PREDESIGN ACTIVITIES

Predesign activities for the pilot water treatment process included bench-scale batch studies of alternative water treatment technologies. The water treatment technologies examined were chemical precipitation/flocculation (polymer flocculation) and chemical precipitation/ microencapsulation (microencapsulation), with bench-scale batch tests conducted on Lake Okeechobee dredge water samples.

The polymer flocculation studies were conducted on the supernatant of a dredge spoil sample, which was treated with a chemical precipitator (ferric chloride) and a flocculating agent (a high-molecular-weight polymer). Ferric chloride is used as a binding and precipitating agent for phosphorus species. Polymer is added to increase the size of floc, which further enhances precipitation.

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[1]Chemical Treatment Followed by Solids Separation Advanced Technology Demonstration Project." Final Report prepared by HAS Engineers & Scientists for the South Florida Water Management District (Contract # E10650). Dec 2000.

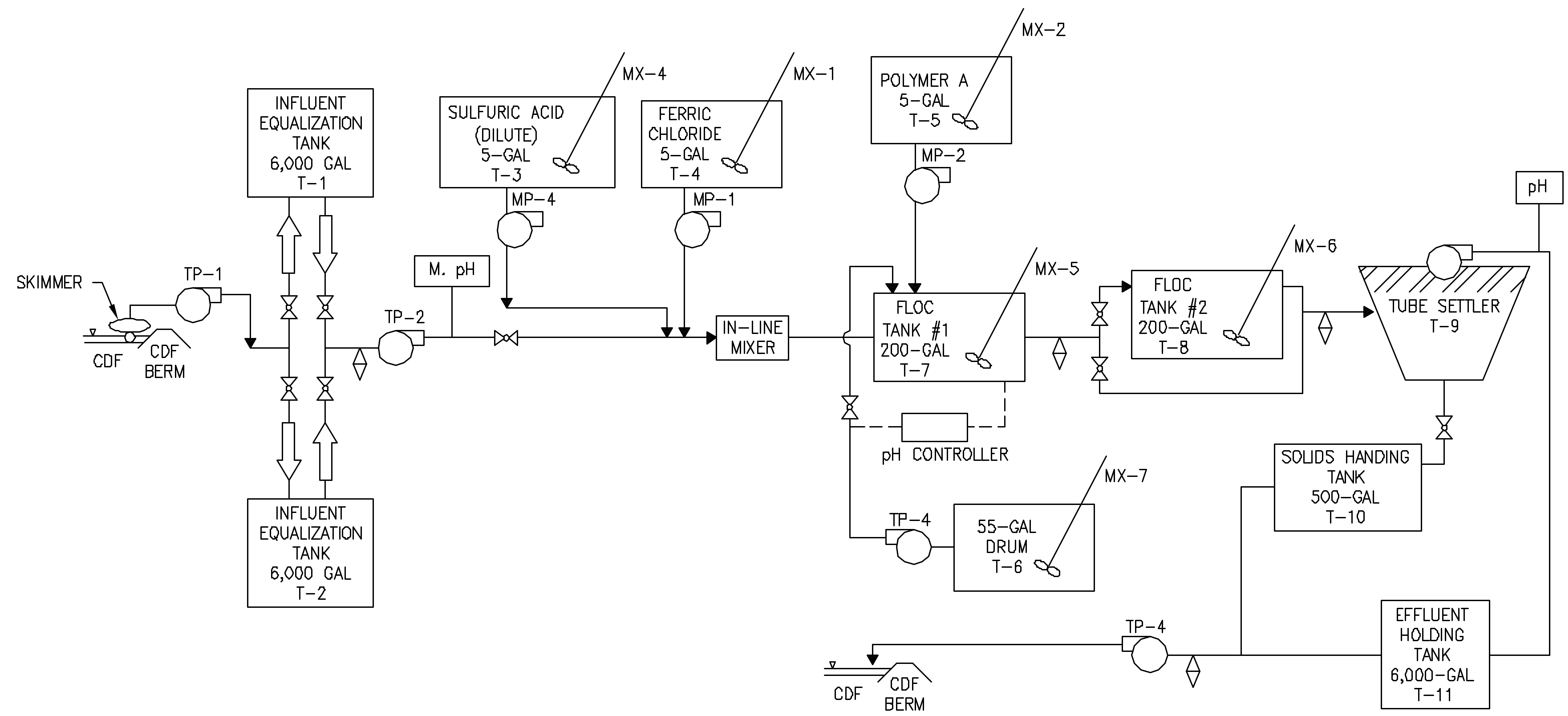
The microencapsulation studies were conducted on the supernatant of a dredge spoil sample, which was treated with ferric chloride and a proprietary microencapsulating agent (KB-1, KEECO Inc.). After addition of ferric chloride, KB-1 is added to promote precipitation by encapsulating the resultant precipitate in a silica matrix.

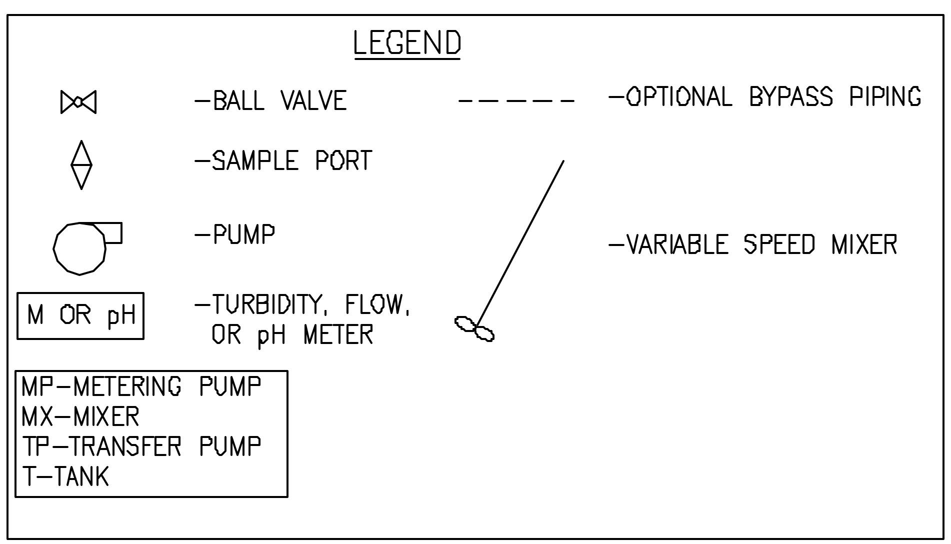
Results of the bench-scale studies indicated that both polymer flocculation and microencapsulation appeared to achieve the target TP of less than or equal to 40 µg/L for the treated samples. These two technologies were deemed suitable for further evaluation during the pilot water treatment processing. A detailed discussion of the bench-scale studies is included in the *Lake Okeechobee Pilot Dredging Project – Sediment Bench-Scale Testing Report* (EA, 2002b).

8.2 DESIGN SPECIFICATIONS

The pilot water treatment process was designed to be a continuous-flow system that would accommodate testing of both the polymer flocculation and microencapsulation technologies. Figure 8-1 presents the conceptual process flow diagram for the system. The key process components of the pilot water treatment system were as follows:

- **Skimmer System (Skimmer and TP-1) –** A floating influent skimmer assembly and pump designed to obtain supernatant from dredge sediments in the CDF subsequent to a settling period.
- **Influent Equalization System (T-1, T-2, and TP-2) –** Two influent equalization tanks and a feed pump. The tanks were designed to hold a volume of water expected to be treated in one day and were designed and installed with the option to provide mixing of the full volume, if necessary.
- **Flocculation Tanks (T-7, T-8, MX-5 and MX-6) –** Two tanks with variable speed mixers designed to provide an environment for the development of flocculation particulates.
- **Settling System (T-9) –** A settling tank with a tube settler pilot assembly inserted into the tank to mechanically encourage the settling/removal of particulates from the flow stream.
- **Chemical Feed System (T-3, T-4, T-5, T-6, MX-1, MX-2, MX-4, and MX-7) –** Three chemical holding tanks with mixers designed to provide continuous mixing. Three chemical metering pumps were also included and were designed to meter accurate and adjustable doses.
- **Ancillary Equipment (includes T-10, T-11, and TP-4) –** In-line mixer to enhance chemical mixing, an effluent holding tank, solids holding tank, and transfer pump to provide flexibility in





CONCEPTUAL PROCESS FLOW DIAGRAM FOR PHOSPHORUS REDUCTION TREATMENT TRAIN

NOTES:

1. PROCESS TO FLOW BY GRAVITY FROM POINT A TO POINT B.
2. PRESSURIZED PIPE SHALL BE 1" SCH. 80 PVC.
3. GRAVITY PIPE SHALL BE 2" SCH. 40 PVC.
4. SOLIDS DISCHARGE VALVE WILL ALSO FUNCTION AS AN EMERGENCY VALVE TO REDUCE TANK VOLUMES DURING OVERFLOW SITUATION.

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EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LAKE OKEECHOBEE
PILOT DREDGING PROJECT

CONCEPTUAL PROCESS FLOW DIAGRAM
FOR PHOSPHORUS REDUCTION TREATMENT TRAIN

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
-	JAP	6/12/02	04630.80	61507.01
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
-	-	NONE	-	8-1

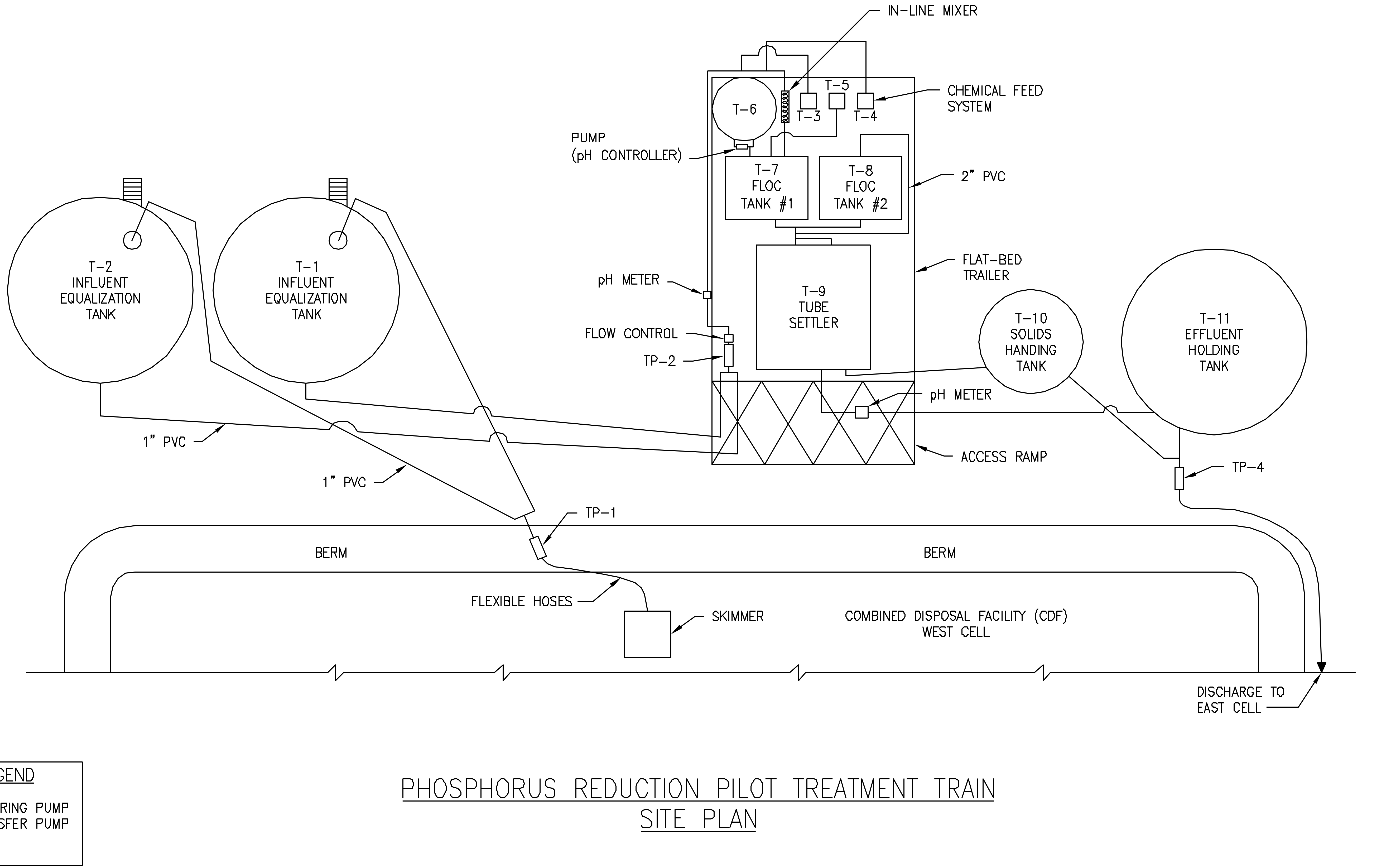
- collection and sampling of system effluent, a flow meter, two pH probes, and several sample ports in various locations in the system.

8.3 CONSTRUCTION

The pilot water treatment process facility was assembled by Engineered Environmental Solutions, Inc. of Deerfield Beach, FL under EA's supervision. The facility was constructed on the western portion of the site, adjacent to the west cell berm of the CDF. Figures 8-2 and 8-3 provide a schematic of the pilot water treatment system and an overview of the site, respectively. The floating skimmer influent system was placed in the west cell, after a sufficient quantity of dredge material had been deposited; while the influent pump (TP-1) that drew water through the influent skimmer system was installed on the berm of the west cell.

Both influent equalization tanks were placed adjacent to the berm to minimize pumping distances for both TP-1 and TP-2. Primary components of the pilot water treatment system were assembled and mounted on a low, flatbed trailer (8 ft x 16 ft [2.4 m x 4.8 m]), which was also positioned adjacent to the berm and north of the influent equalization tanks. The effluent holding tank and solids handling tank were placed directly north of the process trailer. An Operation and Maintenance (O&M) manual was provided by the contractor at the conclusion of construction. As-built photos of the PWTS are included in Appendix F. Minor changes that were made to the system during construction and operation are listed below:

- A valve was installed on the T-6 process line to prevent process backflow into T-6, which was occurring due to as-built hydraulic conditions.
- The tube settler module, originally intended to be a free-floating unit, was stabilized during the operation of the system. The action of the module moving in the tank appeared to cause disturbance of the floc settling within the tubes. To minimize this movement, the tube settler module was mechanically fixed in place in T-9.
- Piping was installed on T-8 to allow for adequate clean out of the tank.

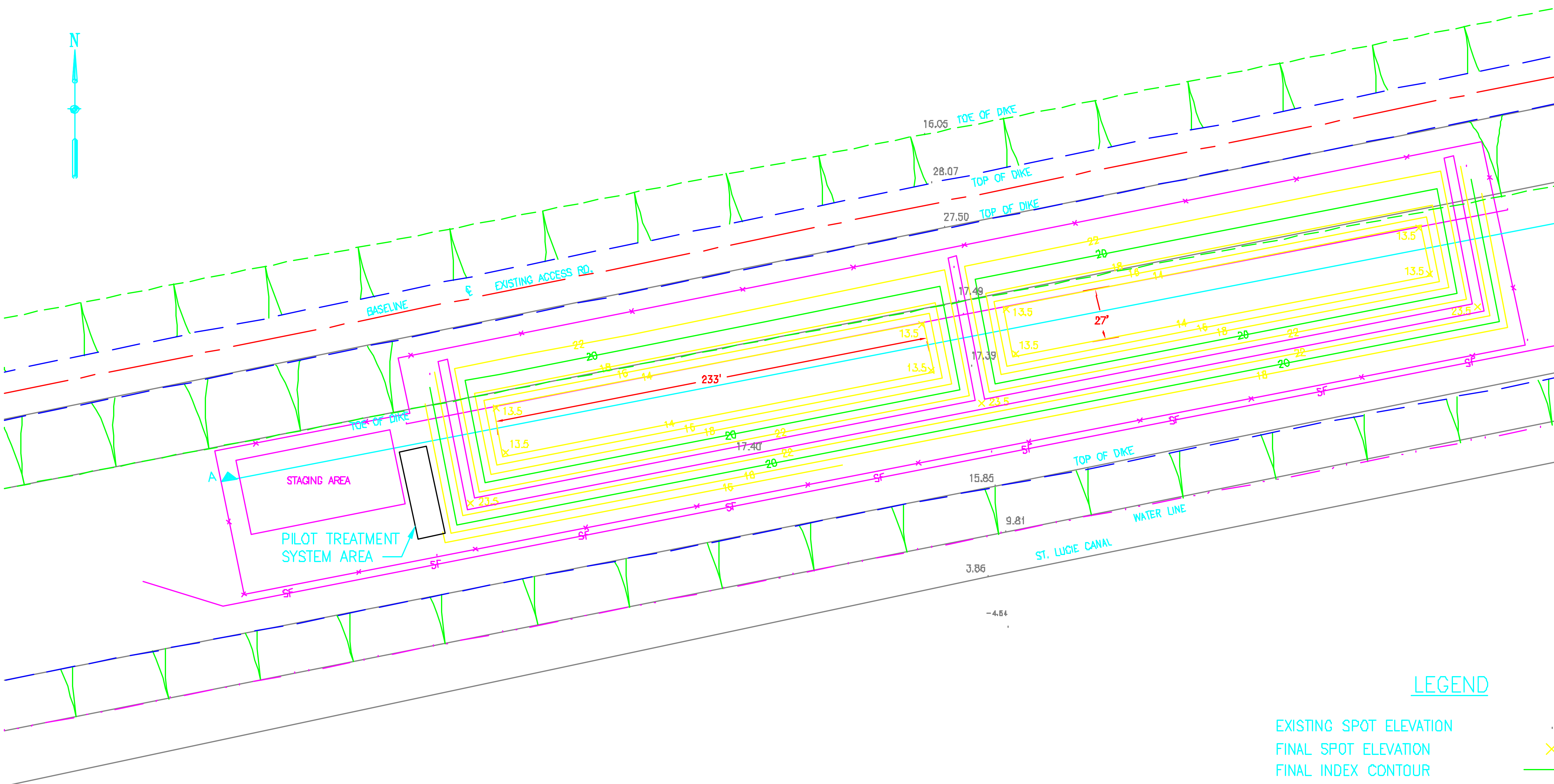


LEGEND

MP-METERING PUMP
TP-TRANSFER PUMP
T-TANK

PHOSPHORUS REDUCTION PILOT TREATMENT TRAIN
SITE PLAN

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	LAKE OKEECHOBEE PILOT DREDGING PROJECT	PHOSPHORUS REDUCTION PILOT TREATMENT TRAIN SITE PLAN	DESIGNED BY -	DRAWN BY JAP	DATE 6/12/02	PROJECT NO. 04630.80	FILE NAME 61507.01
			CHECKED BY -	PROJECT MGR. -	SCALE NONE	DRAWING NO. -	FIGURE 8-2



SITE PLAN

LEGEND

EXISTING SPOT ELEVATION	.9.81
FINAL SPOT ELEVATION	×13.5
FINAL INDEX CONTOUR	20
FINAL INTERMEDIATE CONTOUR	16
TOP OF CDF DIKES	
BASELINE	
SILT FENCE	SF
NEW CHAIN-LINK FENCE	×

60 30 0 60 120

GRAPHIC SCALE IN FEET

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EA ENGINEERING, SCIENCE, AND TECHNOLOGY

LAKE OKEECHOBEE
PILOT DREDGING PROJECT

SITE PLAN

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
-	JAP	6/13/02	04630.80	61507.01
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
-	-	1"=60'	-	8-3

8.4 PROCESS OPERATION

Dredge material removed during the pilot dredging project was deposited in the CDF (west cell) and allowed to settle for approximately 48 hours. A decanting skimmer inlet system was used to pump (TP-1) supernatant from the CDF to two 6,000-gallon (gal) influent equalization tanks (T-1 and T-2).[2] After the equalization tanks were full, the supernatant was sampled and analyzed for TP to calculate the appropriate dosage of ferric chloride. The supernatant was also analyzed for ortho Phosphorus (ortho P), total suspended solids (TSS), and total iron (Fe_{tot}).

After receiving laboratory analysis of the TP concentration, the supernatant was pumped at a rate of 10 gpm through the treatment system. The process flow was dosed with ferric chloride solution upstream of an in-line static mixer. During the chemical precipitation/ micro-encapsulation processing, sulfuric acid was also added. The ferric chloride solution and sulfuric acid were stored in 5 gallons [18.9 L] chemical feed tanks (T-3 and T-4) and then pumped into the process line via chemical-metering pumps (MP-1 and MP-4) to ensure accurate continuous dosage. The influent of the system included a metering instrumentation station that measured the flowrate and pH of the influent supernatant.

After the in-line static mixer, the process stream flowed into a 200 gallon [757 L] working volume flocculation tank (Floc Tank #1, T-7), where it was dosed with polymer (or encapsulating agent) and slowly mixed. The polymer and encapsulating agent were stored in feed tanks (5 gallon [18.7 L] [T-5] and 55 gallon [208 L] [T-6], respectively) and were pumped to the flocculation tank via chemical metering pumps (MP-2 and MP-3) to ensure accurate, continuous dosage. For the microencapsulation technology, the process flow was dosed with sulfuric acid (stored in T-3) prior to Floc Tank 1, since pH adjustment was necessary. The process flow was then directed to a second 200 gallon [757 L] flocculation tank (Floc Tank #2, T-8, working volume = 180 gallon [681 L]), where additional mixing and flocculation occurred.

The process flow was then directed to a settling tank that contained a tube settler module (Tube Settler, T-9) to encourage settling of the floc. A metering station positioned after the settling tank measured the pH of the treated supernatant, which was then pumped to a 4,000 gallon [15,000 L] storage tank (Effluent Holding Tank, T-11) for laboratory and in-situ analysis and eventual return to the CDF (east cell). The accumulated particulates at the base of the tube

[2] Due to a 24-hour lab turnaround time, two equalization tanks were used to allow for continuous processing.

settler were discharged daily to a 400-gal storage tank (Solids Holding Tank, T-10) for qualitative and quantitative analysis and eventual return to the east cell CDF (Figure 8-1). The process utilized gravity flow from Floc Tank #1 to the Solids Holding Tank. Pumps were used to transfer flow in the remainder of the process. With a supernatant flow rate of 10 gpm, the retention time of the continuous flow portion of the system was approximately 1 hour.

During operation of the pilot treatment process, EA employees and subcontractors followed health and safety requirements as outlined in the site *Lake Okeechobee Pilot Dredging Project – Health and Safety Plan* (EA, 2001e) and the Health and Safety Plan Addendum (EA 2002).

8.5 METHODOLOGY

Water treatment was performed from May 30, 2002 through June 8, 2002. Chemical precipitation and flocculation were conducted using ferric chloride (33.7% $FeCl_3$, Engineered Environmental Solutions) and a high-molecular-weight polyacrylamide-based polymer (NALCLEAR 8184, Nalco Chemical Co.), with approximately 11,600 gallons [44,000 L] of supernatant treated during processing.

Chemical precipitation and microencapsulation was conducted using $FeCl_3$ and a microencapsulating agent (KB-1, KEECO Inc.). Sulfuric acid (dilute) was used to adjust the pH of the influent before addition of the microencapsulating agent. Approximately 7,700 gallon [29,000 L] of supernatant was treated during processing.

During operation of the pilot water treatment process, qualitative and quantitative analyses were conducted for treated and untreated supernatant and removed particulates. The following process samples were collected during pilot water treatment processing:

- Influent water characterization samples—immediately after an equalization tank was filled, a water sample was collected and sent to the laboratory for analysis (24-hr turnaround) of TP, ortho P, TSS, and Fe_{tot}. A total of 8 influent water characterization samples were collected during processing.

Effluent water characterization samples—After the completion of each day's treatment processing, effluent water characterization samples were collected and sent to the laboratory for analysis (24-hr turnaround) for some or all of the following: TP, ortho P, TSS, Fe_{tot}, and Priority

Pollutant List (PPL) metals. A total of 14 effluent water characterization samples were collected during processing.

- Water quality samples—Water samples were collected to evaluate the water quality of pre- and post-treatment supernatant. Water quality samples were analyzed for the following analytes: alkalinity, hardness, fecal coliform, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), nitrate and nitrite (total and dissolved), ammonia (dissolved), and dissolved P. A total of four influent and four effluent samples were collected and analyzed for selected parameters to determine "lake readiness" of the treated effluent.

- Particulate samples—Particulate samples were collected to investigate settling times, percent solids, and waste characteristics of particulates removed from the effluent water stream during processing. Particulate settling times were measured in the field, while percent solids and waste characteristics were obtained by laboratory analysis. Analysis for waste characteristics included Toxicity Characteristic Leaching Procedure (TCLP) for some or all of the following: metals, phosphorus, herbicides, and pesticides. A TCLP waste characterization was conducted on the particulates generated from each of the treatment technologies.

- Quality Control (QC) Samples—A total of 7 QC samples were collected during field activities and included two field duplicates analyzed for TP, ortho P, TSS, and Fe_{tot}, one (1) matrix spike/matrix spike duplicate (MS/MSD) analyzed for TP, and four field duplicates analyzed for water quality analytes.

- In-situ measurements recorded during processing included temperature, pH, and turbidity.

Laboratory analysis of water and particulate samples collected during pilot treatment was performed by PPB Environmental Laboratories Inc. (Gainesville, FL) and Phase Separation Science (Baltimore, MD). In-situ pH measurements were collected using +GF+Signet pH/ORP Meter. In-situ turbidity measurements were obtained using a Hach Portable Turbidimeter (Model 2100P).

8.6 RESULTS

8.6.1 Influent

Before processing began, supernatant was pumped from the CDF (west cell) to two 6,000 gallon [22,700 L] influent equalization tanks (T-1 and T-2). Water samples [TANK 1 and TANK 2] were collected on May 27, 2002 and sent to the laboratory for TP analysis. The following analytical results were reported:

TANK 1	TANK 2
TP = 264 µg/L	TP = 260 µg/L

Tables 8-1, 8-2, and 8-3 present the laboratory results that were reported for samples collected during project activities. Criteria and guidance to screen laboratory and field data are presented in Table 8-4.

Since treatment was not started until May 30, 2002, additional water samples (WATER-530-03 and WATER-531-03) were collected to recharacterize the supernatant prior to processing, with the following results:

- TP = 177 µg/L (WATER-530-03)
- ortho P = 103 µg/L (WATER-531-03)
- TSS = 4 mg/L (WATER-531-03)
- Fe_{tot} = 383 µg/L (WATER-531-03).

The influent supernatant was observed to be virtually colorless, with no large suspended or settled particulate matter. The following subsections discuss processing results for the polymer flocculation and microencapsulation technologies.

8.6.2 Polymer Flocculation

The polymer flocculation technology was used to process supernatant from May 30, 2002 through June 3, 2002. A total of seven trials were conducted using various dosages of ferric chloride and polymer. The process flow rate was held constant at 10 gpm [38 l/min].

Table 8-1 Summary of Laboratory Analysis for Pilot Water Treatment System

Date	Time	Sample Name	Analysis								Notes
			P_{tot} (ug/L)	ortho P (ug/L)	Fe_{tot} (ug/L)	TSS (mg/L)	MS/MSD (%)	PPL Metals	% Solids	WQ	
5/27/2002		TANK 1	264	NA	NA	NA	NA	NA	NA	NA	Tank 1 (analysis after filling)
5/27/2002		TANK 2	260	NA	NA	NA	NA	NA	NA	NA	Tank 2 (analysis after filling)
5/30/2002	1215	WATER-530-01	NA	NA	NA	NA	NA	NA	NA	X [3]	Influent
5/30/2002	1640	WATER-530-02	NA	NA	NA	NA	NA	NA	NA	X [3]	Effluent
5/30/2002	1630	WATER-530-03	177	NA	NA	NA	NA	NA	NA	NA	P_{tot} Verification for TANK 2 (5/27/02)
5/30/2002	1640	WATER-530-04	136	91	5640	10	NA	X [2]	NA	NA	Effluent
5/30/2002	1640	DUP-1	NA	NA	NA	NA	NA	NA	NA	X [3]	Duplicate for WATER-530-02
5/31/2002	1350	WATER-531-01	NA	NA	NA	NA	NA	NA	NA	X [3]	Influent
5/31/2002	1350	WATER-531-02	149	52	622	8	NA	NA	NA	NA	Tank 1 (analysis after filling)
5/31/2002	1500	DUP-2	NA	NA	NA	NA	NA	NA	NA	X [3]	Duplicate for WATER-531-01
5/31/2002	1605	WATER-531-03	NA	103	383	4	NA	NA	NA	NA	Analytes not sampled for TANK 1 and TANK 2 analysis (5/27/02)
5/31/2002	1610	WATER-531-04	NA	NA	NA	NA	NA	NA	NA	X [3]	Effluent
5/31/2002	1610	WATER-531-05	87	66	5190	11	NA	NA	NA	NA	Effluent
5/31/2002	1300	S-529530	NA	NA	NA	NA	NA	NA	0.27	NA	Particulates from Solids Holding Tank (T-10)
6/1/2002	1220	WATER-61-01	12	12	5640	14	NA	NA	NA	NA	Effluent (Trial #1)
6/1/2002	1500	WATER-61-02	NA	NA	NA	NA	NA	NA	NA	X [3]	Influent
6/1/2002	1450	WATER-61-03	NA	NA	NA	NA	NA	NA	NA	X [3]	Effluent (Trial #2)
6/1/2002	1455	WATER-61-04	17	7	14200	21	NA	NA	NA	NA	Effluent (Trial #2)
6/1/2002	1500	DUP-3	NA	NA	NA	NA	NA	NA	NA	X [3]	Duplicate for WATER-61-02
6/1/2002	0945	S-531	NA	NA	NA	NA	NA	NA	0.27	NA	Particulates from Solids Holding Tank (T-10)

Table 8-1 Summary of Laboratory Analysis for Pilot Water Treatment System

Date	Time	Sample Name	Analysis								Notes
			P_{tot} (ug/L)	ortho P (ug/L)	Fe_{tot} (ug/L)	TSS (mg/L)	MS/MSD (%)	PPL Metals	% Solids	WQ	
6/2/2002	1210	WATER-62-01	36	ND	40800	61	NA	NA	NA	NA	Effluent (Trial #1)
6/2/2002	1420	WATER-62-02	14	9	12900	17	NA	NA	NA	NA	Effluent (Trial #2)
6/2/2002	1420	WATER-62-03	NA	NA	NA	NA	NA	NA	NA	X [3]	Effluent (Trial #2)
6/2/2002	1430	WATER-62-04	NA	NA	NA	NA	NA	NA	NA	X [3]	Influent (Trial #2)
6/2/2002	1430	DUP-4	NA	NA	NA	NA	NA	NA	NA	X [3]	Duplicate for WATER-62-04
6/2/2002	1445	WATER-62-05	123	43	577	8	NA	NA	NA	NA	Tank 2 (analysis after filling)
6/2/2002	0900	S-61	NA	NA	NA	NA	NA	NA	0.28	NA	Particulates from Solids Holding Tank (T-10)
6/3/2002	1215	WATER-63-01	7	ND	5900	13	94/98 *	NA	NA	NA	Effluent
6/3/2002	1215	DUP-5	8	4	5670	12	NA	NA	NA	NA	Duplicate for WATER-63-01
6/3/2002	14	WATER-63-02	97	10	398	15	NA	NA	NA	NA	Tank 1 (analysis after filling)
6/3/2002	0900	S-62	NA	NA	NA	NA	NA	NA	0.73	NA	Particulates from Solids Holding Tank (T-10)
6/3/2002	1300	S-63-01	NA	NA	NA	NA	NA	NA	0.12	NA	Particulates from Floc Tank #2 (T-8)
6/3/2002	1300	S-63-02	NA	NA	NA	NA	NA	NA	0.25	NA	Particulates from Solids Holding Tank (T-10)
6/5/2002	0952	WATER-6501	19	8	3380	14	NA	NA	NA	NA	Effluent
6/5/2002	1120	WATER-6502	22	7	3020	15	NA	NA	NA	NA	Effluent
6/6/2002	1000	WATER-6601	37	15	4470	19	NA	NA	NA	NA	Effluent
6/6/2002	1125	WATER-6602	30	8	4250	11	NA	NA	NA	NA	Effluent
6/6/2002	1240	WATER-6603	145	27	260	18	NA	NA	NA	NA	Tank 2 (analysis after filling)

Table 8-1 Summary of Laboratory Analysis for Pilot Water Treatment System

Date	Time	Sample Name	Analysis								Notes
			P_{tot} (ug/L)	ortho P (ug/L)	Fe_{tot} (ug/L)	TSS (mg/L)	MS/MSD (%)	PPL Metals	% Solids	WQ	
6/7/2002	1240	WATER-6701	34	21	5850	23	NA	NA	NA	NA	Effluent
6/7/2002	1415	WATER-6702	19	10	2600	11	NA	NA	NA	NA	Effluent
6/8/2002	1000	WATER-6801	29	18	8720	27	NA	NA	NA	NA	Effluent
6/8/2002	1000	WATER-DUP	32	20	8820	29	NA	NA	NA	NA	Duplicate for WATER-6801

X^2 - See Table 8-4 for PPL metal results
X^3 - WQ results are discussed in Chapter 6
WQ - Water Quality
WTP - Water Treatment Parameters
P_{tot} - Total Phosphorus
ortho P - Ortho Phosphorus
TSS - Total Suspended Solids
Fe_{tot} - Total Iron
MS/MSD - Matrix Spike/Matrix Spike Duplicate
PPL - Priority Pollutant List
NA - Not Analyzed
* Spike Recover Control Limits - 87 to 118

Table 8-2 Summary of Laboratory Analysis for PPL Metals (Polymer Flocculation Technology)

			Field sample ID:	WATER-530-04 (Chemical Precipitation/Flocculation)		
			Location:	Effluent Sample - PWTP		
			Sample Date:	05/30/02		
Analyte	**Method**	**Screening Criteria**	**Units**	**Conc**	**DL**	**Flags**
Antimony	200.8	14	µg/L	ND	3.5	
Arsenic	200.7	50	µg/L	ND	2.5	
Beryllium	200.7	0.01	µg/L	ND	0.2	*
Cadmium	200.7	1.77	µg/L	ND	0.4	
Chromium	200.7	329	µg/L	3		
Copper	200.7	19.2	µg/L	7.3		
Lead	200.7	6.53	µg/L	ND	2.4	
Mercury	200.7	0.01	µg/L	ND	0.1	*
Nickel	200.7	254	µg/L	2.2		
Selenium	200.7	5	µg/L	ND	1.4	
Silver	272.2	0.07	µg/L	ND	0.2	*
Thallium	200.7	1.7	µg/L	ND	4.4	*
Zinc	200.7	171	µg/L	30.5		

Results that exceed criteria are shaded

PPL - Priority Pollutant List

ND - Not Detected

PWTP - Pilot Water Treatment Process

* - Detection limit exceeds screening criteria

Table 8-3 Summary of Laboratory Analysis for Waste Characterization of Particulates - Pilot Water Treatment System

			Field sample ID:	Composite Particulate Sample[1] (Chemical Precipitation/Flocculation)			SED (Chemical Precipitation/Microencapsulation)		
			Location:	Effluent Particulates - PWTS			Effluent Particulates - PWTS		
			Sample Date:	6/11/2002 (composite date)			06/08/02		
Method	**Analyte**	**Screening Criteria ***	**Units**	**Conc**	**PQL**	**Flags**	**Conc**	**RL**	**Flags**
	TCLP Phosphorus								
EPA 365.2	Total Phosphorus	40	µg/L	**600**	100		-		
EPA 365.2	Dissolved Phosphorus	40	µg/L	**200**	100		-		
EPA 1311/6010	Total Phosphorus	40	µg/L	-			ND	5	
	TCLP Metals								
EPA 1311/200.8	Arsenic	5	mg/L	ND	0.5		-		
EPA 1311/6010	Arsenic	5	mg/L	-			ND	0.005	
EPA 1311/200.8	Barium	100	mg/L	ND	10		-		
EPA 1311/6010	Barium	100	mg/L	-			0.24		
EPA 1311/200.8	Cadmium	1	mg/L	ND	0.1		-		
EPA 1311/6010	Cadmium	1	mg/L	-			0.0021		
EPA 1311/200.8	Chromium	5	mg/L	ND	0.5		-		
EPA 1311/6010	Chromium	5	mg/L	-			ND	0.001	
EPA 1311/200.8	Lead	5	mg/L	ND	0.5		-		
EPA 1311/6010	Lead	5	mg/L	-			ND	0.003	
EPA 1311/200.8	Mercury	0.2	mg/L	ND	0.1		-		
EPA 1311/7471	Mercury	0.2	mg/L	-			ND	0.0002	
EPA 1311/200.8	Selenium	1	mg/L	ND	0.1		-		
EPA 1311/6010	Selenium	1	mg/L	-			ND	0.005	
EPA 1311/200.8	Silver	5	mg/L	ND	0.5		-		
EPA 1311/6010	Silver	5	mg/L	-			ND	0.005	
	TCLP Herbicides								
EPA 1311/8151	2,4,5-TP (Silvex)	1	mg/L	ND	0.1		-		
EPA 1311/8150	2,4,5-TP (Silvex)	1	mg/L	-			ND	0.05	
EPA 1311/8151	2,4-D	10	mg/L	ND	0.1		-		
EPA 1311/8150	2,4-D	10	mg/L	-			ND	0.005	
	TCLP Pesticides								
EPA 1311/8081	Lindane	0.4	mg/L	ND	0.005		ND	0.0005	
EPA 1311/8081	Heptachlor	0.008	mg/L	ND	0.005		ND	0.0005	
EPA 1311/8081	Heptachlor Epoxide	0.008	mg/L	ND	0.005		ND	0.0005	
EPA 1311/8081	Endrin	0.02	mg/L	ND	0.005		ND	0.0005	

Table 8-3 Summary of Laboratory Analysis for Waste Characterization of Particulates - Pilot Water Treatment System

			Field sample ID:	Composite Particulate Sample[1] (Chemical Precipitation/Flocculation)			SED (Chemical Precipitation/Microencapsulation)		
			Location:	Effluent Particulates - PWTS			Effluent Particulates - PWTS		
			Sample Date:	6/11/2002 (composite date)			06/08/02		
Method	**Analyte**	**Screening Criteria ***	**Units**	**Conc**	**PQL**	**Flags**	**Conc**	**RL**	**Flags**
EPA 1311/8081	Methoxychlor	10	mg/L	ND	0.005		ND	0.0005	
EPA 1311/8081	Toxaphene	0.5	mg/L	ND	0.025		ND	0.002	
EPA 1311/8081	Chlordane	0.03	mg/L	ND	0.025		ND	0.001	

[1] Composite sample composed of S-529530, S-531, S-61, S-62, S-63-01, and S-63-02

Results that exceed criteria are shaded

PQL - Practical quantitation limit

RL - Reporting limit

TCLP - Toxicity Characteristic Leaching Procedure

ND - Not Detected

* Screening criteria for metals, herbicides, and pesticides is based upon Federal regulation outlined in 40 CFR 261.24. The screening criteria for phosphorus is based on the South Florida Water Management District guidance, which is the target concentration of the SWIM Act (Florida Statutes, Sections 373.451 and 373.4595).

Table 8-4 Water Quality Screening Criteria

Analyte	EPA Method	Unit	Limit	Reference
Temperature	NA	°F	5 above NB	a
Turbidity	NA	NTU	29 above NB	a
TSS	160.2	mg/L	-	-
pH	NA	SU	6 - 8.5	a
Total Phosphorus	365.1	µg/L	40	b
Total Iron	200.7	mg/L	0.3	a
Total Nitrogen	351.2	mg/L	10	a
Total Nitrogen - Ino	353.2	mg/L	10	a
PPL Metals				
Antimony	200.8	µg/L	14	a
Arsenic	200.7	µg/L	50	a
Beryllium	200.7	µg/L	0.0077	a
Cadmium [1]	200.7	µg/L	1.77	a
Chromium [2]	200.7	µg/L	329	a
Copper [3]	200.7	µg/L	19.2	a
Lead [4]	200.7	µg/L	6.53	a
Mercury	200.7	µg/L	0.01	a
Nickel [5]	200.7	µg/L	254	a
Selenium	200.7	µg/L	5	a
Silver	272.2	µg/L	0.07	a
Thallium	200.7	µg/L	1.7	a
Zinc [6]	200.7	µg/L	171	a
TCLP Metals				
Arsenic	EPA 1311/200.8	mg/L	5	c
Barium	EPA 1311/200.8	mg/L	100	c
Cadmium	EPA 1311/200.8	mg/L	1	c
Chromium	EPA 1311/200.8	mg/L	5	c
Lead	EPA 1311/200.8	mg/L	5	c
Mercury	EPA 1311/200.8	mg/L	0.2	c
Selenium	EPA 1311/200.8	mg/L	1	c
Silver	EPA 1311/200.8	mg/L	5	c
TCLP Herbicides				
2,4,5-TP (Silvex)	EPA 1311/8151	mg/L	1	c
2,4-D	EPA 1311/8151	mg/L	10	c
TCLP Pesticides				
Lindane	EPA 1311/8081	mg/L	0.4	c
Heptachlor	EPA 1311/8081	mg/L	0.008	c
Heptachlor Epoxide	EPA 1311/8081	mg/L	0.008	c
Endrin	EPA 1311/8081	mg/L	0.02	c
Methoxychlor	EPA 1311/8081	mg/L	10	c
Toxaphene	EPA 1311/8081	mg/L	0.5	c
Chlordane	EPA 1311/8081	mg/L	0.03	c

Notes for this table are on the next page

Table 8-4 Screening Criteria

Notes:

note: Lake Okeechobee is classified as a Class 1 body of surface water (potable water supply)

b - Criteria is based on the South Florida Water Management District guidance, which is the target concentration of the SWIM Act (Florida Statutes, Sections 373.451 and 373.4595)

c - Criteria is based upon Federal regulations outlined in 40 CFR 261.24.

NA - Not Applicable

NB - Natural Background

NTU - Nephalometric Turbidity Units

PPL - Priority Pollutant List

SU - Standard Units

TCLP - Toxicity Characteristic Leaching Procedure

[1] Limit for cadmium must be calculated using the following equation: L = exp(0.7852*ln(H) - 3.49)

where H = hardness (measuresed a mg/L of CaCO3)

Note: For this screening criteria, H has been designated as 176 mg/L, based upon effluent water quality results

[2] Limit for chromium must be calculated using the following equation: L = exp(0.819*ln(H) + 1.561)

[3] Limit for copper must be calculated using the following equation: L = exp(0.8545*ln(H) - 1.465)

[4] Limit for lead must be calculated using the following equation: L = exp(1.273*ln(H) - 4.705)

[5] Limit for nickel must be calculated using the following equation: L = exp(0.846*ln(H) + 1.1645)

[6] Limit for zinc must be calculated using the following equation: L = exp(0.8473*ln(H) + 0.7614)

8.6.2.1 Effluent from Polymer Flocculation

Seven trials were performed for the polymer flocculation technology. Table 8-5 summarizes the process volume, treatment dosages, and laboratory results for influent and effluent target analytes, and in-situ turbidity and pH measurements for each process trial. The target effluent TP concentration (of less than or equal to 40 µg/L) was achieved for five of the seven trials (Trials 3 through 7). During Trials 1 and 2, lower dosages of ferric chloride were used during processing, and the target effluent TP concentration was not achieved. The lowest TP concentration achieved during the processing was obtained during Trial 7, with a reported result of 7 µg/L. The Fe:P molar ratio for these trials ranged from 164 to 288, and the polymer dosages ranged from 14 to 70 mg/L. These results are consistent with results achieved during the bench-scale study of the polymer flocculation technology mentioned in Section 8.1.

However, the following notable observations were recorded during the pilot treatment trials:

- Based upon the bench-scale studies, pH adjustment was not anticipated to be necessary during pilot processing. However, during the pilot water treatment trials, the pH for the treated effluent was observed to be considerably lower than pH levels recorded during the bench-scale studies (the pH differed by at least 2 units) even though similar chemical dosages were used. The pH range measured after chemical addition during the bench-scale studies was 5.6 to 6.6, versus a pH range of 2.8 to 4.3 for pilot Trials 3 through 7. Although it is not clear why disparity exists between the pH levels for the two treatment events, the low pH observed during the pilot water treatment trials may have affected the amount of coagulation that was achieved by the ferric chloride.[3] Thus, it is possible that lower chemical dosages may yield better TP removal if the pH is regulated during processing. It should be noted that the effluent pH of Trials 3 through 7 fail to meet the project screening criteria of pH range 6–8.5 (See Table 8-4).

- During processing, floc (in varying sizes and amounts) were observed to pass through the settling module for each trial. These field observations are consistent with laboratory results, which reveal that the TSS of treated effluent was greater than untreated influent TSS. It should be noted that it was expected that TSS would increase during the chemical addition steps of the process, due to both the precipitation of dissolved species by the ferric chloride

[3]According to literature, effective phosphorus removal can be achieved within the range of pH 5.5 to 7.0 (Metcalf & Eddy, Inc. Wastewater Engineering – Treatment, Disposal, and Reuse. Third Edition. Irwin McGraw-Hill. 1991.)

and the addition of the polymer. However, based upon observations and laboratory analysis conducted during the bench-scale studies, it was also expected that after the settling step TSS levels of the effluent would be lower than TSS levels of the influent. Several factors may potentially account for the elevated TSS levels in the PWTS effluent, such as:

- Insufficient settling time in the Tube Settler (T-9)
- Insufficient settling by the Tube Settler Module
- Insufficient floc formation in Floc Tanks #1 and #2 (T-7 and T-8, respectively), which may be caused by tank dimensions or the stirring dynamics of the tank mixers.

- It should be noted that in-situ turbidity measurements were, in general, lower for the effluent versus the influent. However, turbidity is a function of suspended and colloidal material (as well as dissolved), colored substances and microscopic organisms. Thus, correlation of turbidity and TSS may be difficult due to variations in the light-absorbing (or scattering) properties of these constituents within a fluid.[4]

- Iron concentrations of processed effluent were higher (by an order of magnitude) than concentrations reported for the influent, which is not consistent with results obtained during the bench-scale studies.[5] It should also be noted that the concentrations reported for total iron in the effluent samples fail to meet the project screening criteria of 3000 mg/L (see Table 8-4).

- One sample, (WATER-530-04), was analyzed by the laboratory for PPL metals. Results of the analysis indicate that no detected analytes exceeded screening criteria (see Table 8-2).

In summary, the polymer flocculation technology reduced supernatant total phosphorus concentrations to less than 40 µg /L in five out of seven tests. The total phosphorus limit was not attained in two of the tests due to inadequate addition of the ferric chloride. However, effluent requirements were not met by this technology, due to the elevated pH and iron concentrations in the effluent.

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[4] American Public Health Association, American Water Works Association, Water Environment Federation. Standard Methods for the Examination of Water and Wastewater. 20th Edition. 1998.

[5] Laboratory results for effluent in the bench-scale studies indicated that iron concentrations decreased by up to approximately 1/3 of the influent iron concentration of 1740 µg/L.

Table 8-5 Summary of Polymer Flocculation Processing

	Influent																Effluent					
Date	Trial #	Volume Processed (gal)	Treatment time (min)	TP (ug/L)	ortho P (ug/L)	Fe_{tot} (ug/L)	TSS (mg/L)	Turb *	pH *	Ferric Chloride Used (g/L)	Total Ferric Chloride Used (g)	Ferric Chloride Cost[2] ($)	Fe:P molar ratio	Polymer Used[1] (mg/L)	Total Polymer Used[1] (g)	Polymer Cost ($)	TP (ug/L)	ortho P (ug/L)	Fe_{tot} (ug/L)	TSS (mg/L)	Turb *	pH *
5/30/2002	1	2411	241.1	177	103	383	4	17	7.5	0.0259	236.4	1.1	28	28.2	257.3	<0.01	136	91	5640	10	14	6.6
5/31/2002	2	2612	261.2	177	103	383	4	15	7.4	0.0259	256.1	1.2	28	42.3	418.2	<0.01	87	66	5190	11	11	6.7
6/1/2002	3	1219	121.9	177	103	383	4	19.2	7.8	0.152	701.3	3.4	164	13.9	64.1	<0.01	**12**	12	5640	14	NA	3.8
6/1/2002	4	1460	146	177	103	383	4	19.2	8.2	0.16	884.2	4.2	173	14.1	77.9	<0.01	**17**	7	14200	21	7.27	3.3
6/2/2002	5	1228	122.8	149	52	622	8	15.3	7.9	0.225	1045.8	5.0	288	51.6	239.8	<0.01	**36**	ND	40800	61	27.4	2.8
6/2/2002	6	1183	118.3	149	52	622	8	15.3	7.9	0.182	814.9	3.9	233	42.9	192.1	<0.01	**14**	9	12900	17	NA	3.2
6/3/2002	7	1445	144.5	123	43	577	8	12.9	7.8	0.136	743.8	3.6	211	72.55	396.8	<0.01	**7**	ND	5900	13	5.04	4.3

[1] 0.01% NALCLEAR 8184 polymer solution

[2] Ferric chloride costs are based upon the one-time chemical costs associated with the PWTS processing and do not represent potential future costs associated with scale-up of this technology.

* - indicates average value

TP - Total Phosphorus

ortho P - Ortho Phosphorus

TSS - Total Suspended Solids

Fe_{tot} - Total Iron

NA - Not Analyzed

ND - Not Detected

8.6.2.2 Particulates from Polymer Flocculation

A total of 6 particulate samples were collected to investigate settling times, percent solids, and waste characteristics of particulates that were removed from the effluent water stream during processing.

Particulate Settling and Percent Solids

One particulate sample (S-63-01) was collected to characterize settling within the Tube Settler Tank (T-9), while the remainder of the samples were collected to characterize settling within the Solids Handling Tank (T-10). Each of the collected particulate samples were allowed to settle undisturbed, and the particulate volumes were measured periodically to determine settling rates. Table 8-6 presents the settling data collected for each of the particulate samples. Figures 8-4 and 8-5 present graphical representations of the data. A discussion of the data is provided in the subsections below.

Tube Settler Characterization – Based upon field observations and results of the settling data for S-63-01, the majority of bulk settling for this sample occurs within the first hour, with a small amount of compression settling occurring over the next 23 hours (see Figure 8-4). It should be noted that the bulk settling time mentioned above is less than the settling times observed during the bench-scale studies, with settling times equal to approximately 3 hours.

At 24:00 hours, the ratio of saturated solids to supernatant for S-63-01 is approximately 28:972, yielding a particulate content of 2.77 % solids (saturated). Thus, the saturated volumetric phase ratio (at t = 24 hours) of the effluent is calculated to be 27.7 mL solids per 1000 mL untreated effluent[6]. The field observations and measurements seem to indicate that approximately one hour (or equivalent time, based on tube settler efficiency) is necessary to achieve successful particulate removal during processing. However, it should be noted that the settling characterization is based upon batch conditions, which may not be entirely characteristic of the continuous flow process. Laboratory results indicate that the percent solids for this sample were 0.12%.

[6] It should be noted that the saturated volumetric phase ratio is time dependent. Also, since the volumetric ratio of treatment chemicals to untreated supernatant is small (approx. 0.002 gal chemicals/gal supernatant), the saturated volumetric phase ratio can be assumed to be the ratio of saturated particulates to untreated supernatant.

Table 8-6 Particulate Settling Data - Polymer Flocculation Technology

S-529530 (Collected on 5/31/02 at 1300)

Diameter of container (cm) = 8.00
Cross-sectional area of container (cm^2) = 50.27

Date/Time	Effective Time (hr)	Height of Layer - from bottom of container (cm)	Volume of Particulate Layer (mL)
5/31/2002 13:00	0:00:00	10.3	517.7
5/31/2002 14:00	1:00:00	5.7	286.5
5/31/2002 15:00	2:00:00	5.1	256.4
5/31/2002 16:00	3:00:00	4.8	241.3
6/1/2002 8:00	19:00:00	4.4	221.2
6/1/2002 13:30	24:30:00	4.1	206.1
6/3/2002 9:00	68:00:00	4	201.1
6/4/2002 9:00	92:00:00	3.7	186.0
6/4/2002 13:00	96:00:00	3.7	186.0

S-531 (Collected on 6/1/02 at 0945)

Diameter of container (cm) = 5.9388
Cross-sectional area of container (cm^2) = 27.70

Date/Time	Effective Time (hr)	Height of Layer - from bottom of container (cm)	Volume of Particulate Layer (mL)
6/1/2002 9:45	0:00:00	36.1	1000.0
6/1/2002 11:45	2:00:00	10.6	293.6
6/1/2002 12:45	3:00:00	8.8	243.8
6/1/2002 13:45	4:00:00	8.1	224.4
6/2/2002 9:45	24:00:00	5.6	155.1
6/3/2002 9:00	47:15:00	5	138.5
6/4/2002 9:00	71:15:00	4.5	124.7
6/4/2002 13:00	75:15:00	4.5	124.7

S-61 (Collected on 6/2/02 at 0900)

Diameter of container (cm) = 9.00
Cross-sectional area of container (cm^2) = 63.62

Date/Time	Effective Time (hr)	Height of Layer - from bottom of container (cm)	Volume of Particulate Layer (mL)
6/2/02 09:00	0:00:00	15	954.3
6/2/02 10:00	1:00:00	9.1	578.9
6/2/02 11:00	2:00:00	7	445.3
6/2/02 12:00	3:00:00	6	381.7
6/2/02 13:00	4:00:00	5.3	337.2
6/3/02 09:00	24:00:00	3.9	248.1
6/4/02 09:00	48:00:00	3.6	229.0
6/4/02 13:00	52:00:00	3.6	229.0

Table 8-6 Particulate Settling Data - Polymer Flocculation Technology

S-62 (Collected on 6/3/02 at 0900)

Diameter of container (cm) = 5.9388
Cross-sectional area of container (cm^2) = 27.70

Date/Time	Effective Time (hr)	Height of Layer - from bottom of container (cm)	Volume of Particulate Layer (mL)
6/3/02 09:00	0:00:00	36.1	1000.0
6/3/02 10:00	1:00:00	35.6	986.1
6/3/02 11:00	2:00:00	35.1	972.3
6/3/02 12:30	3:30:00	34.3	950.1
6/3/02 14:00	5:00:00	33.6	930.7
6/4/02 09:00	24:00:00	26.1	723.0
6/4/02 13:00	28:00:00	25.2	698.1

S-63-01 (Collected on 6/3/02 at 1300)

Diameter of container (cm) = 5.9388
Cross-sectional area of container (cm^2) = 27.70

Date/Time	Effective Time (hr)	Height of Layer - from bottom of container (cm)	Volume of Particulate Layer (mL)
6/3/02 13:00	0:00:00	36.1	1000.0
6/3/02 14:00	1:00:00	1.5	41.6
6/4/02 09:00	20:00:00	1	27.7
6/4/02 13:00	24:00:00	1	27.7

S-63-02 (Collected on 6/3/02 at 1300)

Diameter of container (cm) = 5.9388
Cross-sectional area of container (cm^2) = 27.70

Date/Time	Effective Time (hr)	Height of Layer - from bottom of container (cm)	Volume of Particulate Layer (mL)
6/3/02 13:00	0:00:00	36.1	1000.0
6/3/02 14:00	1:00:00	11.3	313.0
6/4/02 09:00	20:00:00	4.5	124.7
6/4/02 13:00	24:00:00	4.5	124.7

Figure 8-4 Settling Characteristics of Tube Settling Tank

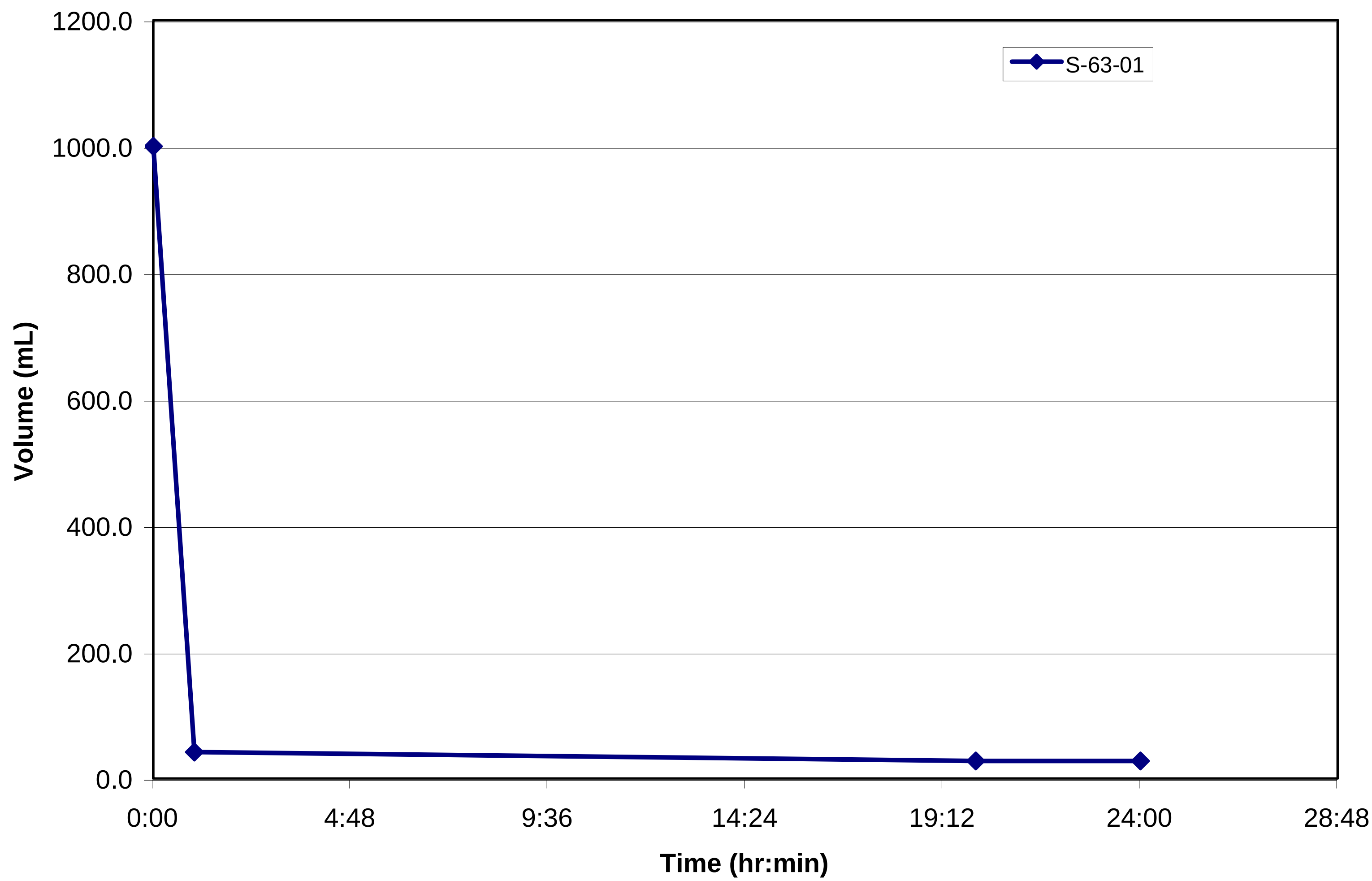
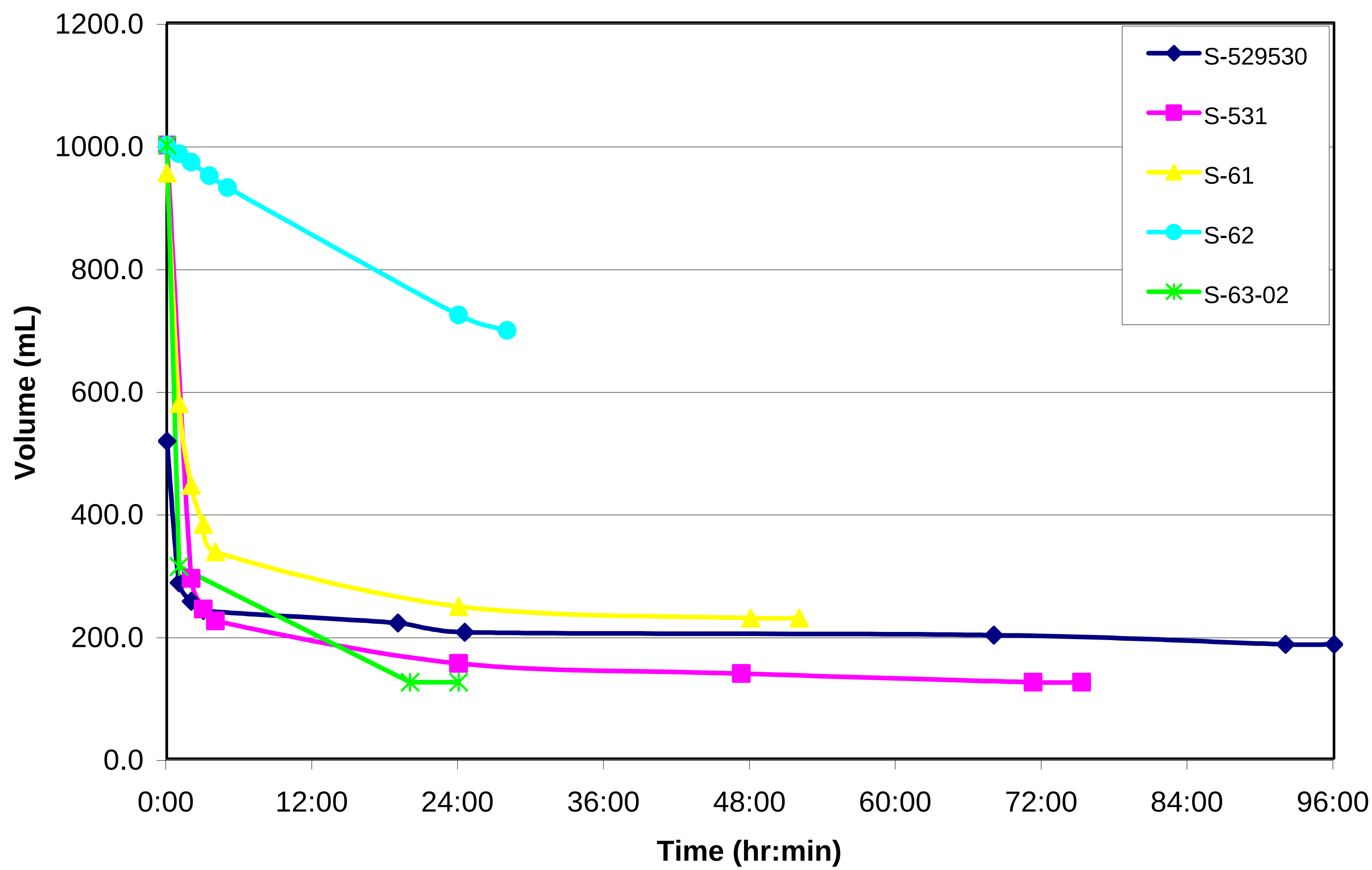


Figure 8-5 Settling Characteristics of Solids Handling Tank



Solids Handling Tank Characterization – Laboratory data (and field observations) for particulate samples S-529530, S-531, S-61, S-62, and S-63-02 indicate that the majority of bulk settling occurs within the first hour, with compression settling occurring over the next 23 hours (see Figure 8-5). It should be noted that Sample S-62 does not appear to have the same settling characteristics as the other samples, possibly indicating that a representative sample of the particulates/residual effluent may not have been collected from within the Solids Settling Tank.

The percent solids results for these samples were within the range of 0.25 to 0.28%, except for sample S-62, which had a percent solids result of 0.73%. The noticeably higher percent solids result for S-62, compared to the other samples, would be characteristic of the higher volume of particulates observed during settling (Figure 8-5).

Particulate Waste Characterization – Particulate waste characterization included TCLP analysis for metals, herbicides, and pesticides, and phosphorus on a composite of Samples S-529530, S-531, S-61, S-62, S-63-01, and S-63-02. It should be noted that Federal criteria do not exist for phosphorus. A guidance level of 40 µg/L was used to screen for phosphorus in order to be consistent with the project target goal for effluent. Laboratory results of the analysis are included in Table 8-3. As the data shows, non-detectable concentration levels were reported for metals, herbicides, and pesticides. Results for dissolved phosphorus show a concentration of 200 µg/L, indicating that the phosphorus has leached from the particulates. Thus, the data indicate that disposal options for particulates may require consideration.

8.6.3 Chemical Precipitation/Microencapsulation

The microencapsulation technology was used to process supernatant from June 4, 2002 through June 8, 2002. A total of seven trials were conducted using various dosages of ferric chloride, sulfuric acid, and microencapsulating agent. The process flow rate was held constant at 10 gpm [38 l/min]. Table 8-7 summarizes the process volume, treatment dosages, laboratory results for influent and effluent target analytes, and in-situ pH measurements for each process trial.

Trials 1 through 7 had effluent TP concentrations that achieved the target goal of less than or equal to 40 µg/L. The lowest TP concentration achieved during the processing was obtained during Trials #1 and #6, with reported results of 19 µg/L. The Fe:P molar ratio for these trials ranged from 131 to 261, and the sulfuric acid dosages (0.05% solution) ranged from 0 to 2.18

ml/L. The total amount of microencapsulating agent used during the seven trials was approximately 25 lbs [11.34 kg] (dry weight).[7]

The following notable observations were recorded during the pilot treatment trials:

- No particulates were observed to pass through the settling module during processing trials.
- Higher-than-expected chemical usage was necessary during processing.
- Iron concentrations of processed effluent were higher (by an order of magnitude) than concentrations reported for the influent.

In summary, the microencapsulation technology appeared to reduce supernatant phosphorus concentrations to less than 40 µg/L.

Particulate Waste Characterization – Particulate waste characterization included TCLP analysis for metals, herbicides, and pesticides, and phosphorus. It should be noted that Federal criteria do not exist for phosphorus. A guidance level of 40 µg/L was used to screen for phosphorus in order to be consistent with the project target goal for effluent. Laboratory results of the analysis are included in Table 8-3. As the data shows, non-detectable concentration levels were reported for all analytes.

8.6.4 Quality Control

A total of 7 Quality Control (QC) samples were collected during pilot water treatment processing, and included two field duplicates analyzed for TP, ortho P, TSS, and Fe_{tot}, one MS/MSD analyzed for TP, and four field duplicates analyzed for water quality analytes (Table 8-8).

[7] Daily consumption of the microencapsulating agent was not recorded.

Table 8-7 Summary of Microencapsulation Processing

	Influent															Effluent				
Date	Trial #	Volume Processed (gal)	Treatment Time (min)	TP (ug/L)	ortho P (ug/L)	Fe_{tot} (ug/L)	TSS (mg/L)	pH	Ferric Chloride Used * (g/L)	Total Ferric Chloride Used * (g)	Ferric Chloride Cost[1] ($)	Fe:P molar ratio *	Sulfuric Acid (0.05%) Used* (mL/L)	Total Sulfuric Acid (0.05%) Used* (mL)	Sulfuric Acid Cost[1] ($)	TP (ug/L)	ortho P (ug/L)	Fe_{tot} (ug/L)	TSS (mg/L)	pH
6/5/2002	1	1110	111	97	10	398	15	7.5	0.132	556.065	2.66	261	2.18	9158.94	20.20	**19**	8	3380	14	7.5
6/5/2002	2	1000	100	97	10	398	15	7.6	0.110	417.467	2.00	217	0.73	2750.43	6.07	**22**	7	3020	15	7.7
6/6/2002	3	1120	112	97	10	398	15	8.0	0.088	374.050	1.79	174	0.73	3080.49	6.80	**37**	15	4470	19	7.6
6/6/2002	4	1020	102	97	10	398	15	8.1	0.121	468.397	2.24	239	1.45	5610.88	12.38	**30**	8	4250	11	7.8
6/7/2002	5	1130	113	145	27	260	18	8.4	0.099	424.564	2.03	131	1.45	6215.98	13.71	**34**	21	5850	23	7.4
6/7/2002	6	1160	116	145	27	260	18	8.4	0.143	629.540	3.01	189	0.73	3190.50	7.04	**19**	10	2600	11	7.4
6/8/2002	7	1130	113	145	27	260	18	8.1	0.154	660.432	3.16	203	0.00	0.00	0.00	**29**	18	8720	27	7.2

[1] Ferric chloride and sulfuric acid costs are based upon the one-time chemical costs associated with the PWTS processing and do not represent potential future costs associated with scale-up of this technology.

TP - Total Phosphorus

ortho P - Ortho Phosphorus

TSS - Total Suspended Solids

Fe_{tot} - Total Iron

NA - Not Analyzed

* - Approximate value

Table 8-8 Summary of Quality Control Samples for PWTS

Date	Time	Sample Name	Analysis					Notes
			P_{tot} (ug/L)	ortho P (ug/L)	Fe_{tot} (ug/L)	TSS (mg/L)	MS/MSD (%)	
Duplicate Samples								
6/3/2002	1215	DUP-5	8 (7)	4 (ND)	5670 (5900)	12 (13)	-	Duplicate for WATER-63-01 (results shown in brackets)
6/8/2002	1000	WATER-DUP	32 (29)	20 (18)	8820 (8720)	29 (27)	-	Duplicate for WATER-6801 (results shown in brackets)
MS/MSD								
6/3/2002	1215	WATER-63-01	-	-	-	-	94/98	Spike recovery limits - 87 to 118

P_{tot} - Total Phosphorus
ortho P - Ortho Phosphorus
TSS - Total Suspended Solids
Fe_{tot} - Total Iron
MS/MSD - Matrix Spike/Matrix Spike Duplicate

9.0 OBSERVATIONS & RECOMMENDATIONS

9.1 SEDIMENT CHARACTERIZATION

9.1.1 Physical Characterization

The targeted mud layer at the PDS was characterized by average bulk density of 1.20 g/cm^3, mean solids content of 21 percent by weight, and average total organic content of 37 percent by weight (Table 4-1). Physical properties of the dredged slurry compare favorably with those of the target mud layer (Table 5-8).

9.1.2 Chemical Characterization

Comparison of Lake Okeechobee sediment concentrations from the PDS to selected screening values indicated that Threshold Effect Concentrations (TECs), Threshold Effect Levels (TELs), and Effects Range – Low (ER-Ls) were exceeded for total cadmium and total mercury concentrations regardless of the screening value source. Arsenic TELs and ER-Ls were exceeded, however arsenic TECs (MacDonald et al., 2000) were not exceeded.

For mercury, both the TEL and the PEL value put forth by Smith et al. (1996) was exceeded. Mercury TEC from MacDonald et al. (2000), mercury PEL from MacDonald et al. (1996) and mercury ER-M from Long et al. (1995) were not exceeded at either of the two locations sampled. Note that only total mercury was analyzed in all samples; no clean sampling or ultra trace analyses was conducted for mercury or any of the other metals.

In addition, sediment concentrations were also compared to soil cleanup target levels (FAC 62-777). Results indicated that except for arsenic, concentrations of the other constituents were below the soil cleanup target level, where available.

Long and MacDonald (1998) published a perspective paper on the interpretation of sediment screening values. Their recommendation was to use ER-M and PEL screening values to establish quotients (measured concentrations/ER-M or PEL) as a tool to rank sites from lowest priority to highest priority. Using this as a ranking tool places these sediments into the lowest priority sites (Long and MacDonald 1998) (Table 4-4). The mean ER-M quotient was 0.15, slightly above the low to medium-low priority cutoff of 0.1, and the mean PEL quotient was 0.3, again just slightly above the low to medium-low priority cutoff.

Only a single Smith et al. (1996) TEL was exceeded (mercury), and the mean TEL quotient was between 0.11 and 1.5 at 0.30 based on Smith et al. (1996) work. No freshwater sediment consensus PECs were exceeded, and only cadmium and mercury TECs exceeded the maximum measured concentrations. Similar to Smith et al. (1996) rankings, these sediments would fall within the "medium-low priority" ranking. Similar ranks were found for the lake sediments relative to MacDonald et al. (2000), MacDonald et al. (1996) and Long et al. (1995) screening values.

Based on the above assessment, it was concluded that the metals detected in the sediments collected from the PDS, while they are not in the lowest priority range, are of minimal concern and should not pose a significant environmental risk.

9.2 OBSERVATIONS FROM ENVIRONMENTAL MONITORING

9.2.1 Water Quality Monitoring

- Review of the in-lake water quality monitoring data indicated no significant difference in water quality (selected nutrients and metals) between samples collected upstream and downstream of the dredging area, as compared to the samples collected within the active dredging zone.

- Concentration of metals recorded in the water column were compared to FDEP's water quality criteria (FAC 62-302.400) for Class I surface water bodies. The comparison indicated that except for one (out of four) iron values, which exceeded the criteria (measurement of 3,230 µg/L compared to criteria of 3,000 µg/L), all other metal concentrations were below the water quality criteria for Class I water bodies.

- Turbidity monitoring data indicated no significant impact on lake turbidity levels during dredging. Turbidity values recorded before, during, and after dredging was completed did not differ from each other significantly. The background lake turbidity levels were relatively high (>50 NTU) and the operation of the SEDCUT® unit did not significantly increase water column turbidity levels.

- Occasional spikes were observed in the turbidity measurements, however, it could not be determined if the spikes were caused by movement of boats and/or equipment or the SEDCUT® operations. No turbidity plume was observed during the monitoring.

- Water quality monitoring for determining lake readiness of the effluent from the pilot water treatment system indicated the PWTS effluent showed pH levels and iron concentrations higher than project screening criteria.

- None of the QA/QC samples indicated problems with sample collection, handling, or analyses.

9.2.2 Hydrographic Surveys

The results of the hydrographic surveys indicate that measurements of the 30 cm [12 in] upper layer of fluid mud, is extremely difficult to quantify. The surveys results were able to reveal the presence of dredging lanes that were approximately 30 cm [12 in] deeper, however, they also were able to reveal to presence of heavy shoaling in the dredge areas, thus limiting their usefulness. Because of the site conditions (heavy weather- wind and waves), characteristics of the fluid mud (low bulk density), and the absence of a denser sand substrate, data from both the multi-beam and dual frequency surveys were not able reveal the precise vertical dredge depths nor the horizontal extend of the dredge area.

While a notable difference could be identified from the progress and post-dredge surveys, a quantifiable interpretation as to the exact vertical depth and horizontal extent could not be determined. The post-dredging survey, which was conducted two weeks after the pilot dredging was completed, showed that majority of the dredged areas previously identified (by the progress dredge survey) as being deeper than the surrounding area, were filled in. The shoaling was noted to be small in height but expansive in area. The nature and the magnitude of the shoaling could not be determined.

9.3 OBSERVATIONS FROM WATER TREATMENT

- The polymer flocculation treatment technology yielded the following results for TP removal:

Date	Trial #	Volume Processed (gal)	Influent TP (µg/L)	Effluent TP (µg/L)
5/30/02	1	2411	177	136
5/31/02	2	2612	177	87
6/1/02	3	1219	177	12
6/1/02	4	1460	177	17
6/2/02	5	1228	149	36
6/2/02	6	1183	149	14
6/3/02	7	1445	123	7

TP - Total Phosphorus

Based on the results summarized above for the polymer flocculation process, five out of seven process trials met the project target reduction goal of 40 µg/L. During Trials 1 and 2, lower dosages of ferric chloride were used during processing, and the target effluent TP concentration was not achieved.

- The microencapsulation treatment technology yielded the following results for TP removal:

Date	Trial #	Volume Processed (gal)	Influent TP (µg/L)	Effluent TP (µg/L)
6/5/02	1	1110	97	19
6/5/02	2	1000	97	22
6/6/02	3	1120	97	37
6/6/02	4	1020	97	30
6/7/02	5	1130	145	34
6/7/02	6	1160	145	19
6/8/02	7	1130	145	29

TP - Total Phosphorus

Based on the results summarized above for the microencapsulation process, seven out of seven process trials achieved the project target reduction goal of 40 µg/L.

- Effluent pH values of less than 6 were frequently observed during the polymer flocculation trials. Five out of seven trials failed to meet the project screening criterion for pH (range 6 – 8.5).

- Particulates produced as a result of the polymer flocculation process were observed to be light and difficult to settle.

- Particulates produced as a result of the microencapsulation process were observed to be denser than the polymer flocculation particulates and settled more readily.

- Polymer flocculation particulate waste characterization results for dissolved and total phosphorus show leachable concentrations of 200 µg/l and 600 µg/L, respectively. Thus, disposal options for these particulates may require consideration.

- Microencapsulation particulate waste characterization results indicated concentrations below detection limits for all tested analytes.

- Iron concentrations of processed effluent for both polymer flocculation and microencapsulation technologies were higher (by an order of magnitude) than concentrations reported for the influent. The concentrations reported for iron in the effluent samples fail to meet the project screening criteria of 3000 mg/L.

9.4 SCALABILITY

9.4.1 Scalability Considerations for the SEDCUT® Dredge Head

Results from the pilot dredging field demonstration indicate that the SEDCUT® technology is capable of selectively removing the Lake Okeechobee mud layer with little dilution water uptake and minimal resuspension impacts to the surrounding area. It therefore merits serious consideration as a viable option in the ongoing Lake restoration initiatives.

Previous studies have shown that this nutrient–laden mud layer serves as a permanent sink within the Lake and continues to add phosphorus to the water column. While progress has been made in controlling phosphorus-laden runoff into the lake from external sources, the Lake continues to be eutrophic, in large part due to the existing mud layer. Unless this layer is removed (or otherwise dealt with through options such as chemical treatment, capping, etc.), lake recovery will be significantly delayed.

For the inherent reasons associated with conventional hydraulic dredging operations (excessive dilution water, resuspension impacts and low production efficiencies in removing thin layers of mud from this type of environment), the SEDCUT® technology offers true promise as a viable restoration option for Lake Okeechobee.

The SEDCUT® technology is based on three inherently scalable fundamental principals, namely:

1. An intake visor (i.e. mouth opening height) that limits the amount of dilution water entrained during dredging,
2. Buoyancy tanks that can control substrate contact pressure, so the dredge head can slide on a selected substrate density plain, and
3. Mud gathering rates equal to or slightly greater than dredge pumping rate.

All three of these design principles were tested during the field demonstration and were shown to be effective, giving the technology an edge over the more conventional hydraulic dredging options.

9.4.2 Conceptual Approach for Large-scale Commercial Dredging in Lake Okeechobee

A conceptual approach is presented below for conducting large-scale commercial dredging in Lake Okeechobee. This approach is based on the results from the pilot-scale field demonstrations conducted by EA, and is aimed at removing up to 200 million cubic yards [153 million m^3] of fluid muds from the lake over 10, 15 and 30-year period.

Daily and yearly production rates are forecasted based on the following assumptions:

1. 200 million cubic yards [153 million m^3] of fluid muds from the lake.
2. The SEDCUT® dredging technology will produce dredge slurry containing 65% target mud and 35% dilution water. (Note that this ratio was obtained at the dredge travel speed of 40 fpm – the maximum that could be attained by the pilot unit. Data shows that the percentage of muds in the dredge slurry increases with travel speed and therefore it can be concluded that higher travel speeds could potentially produce a higher percentage of sediments.

3. Dredge operations will be run continuously (24 hours/day 7 days /week) with 15% allowance for downtime.
4. Dredge slurry can be stored in an unlined containment facility.
5. Dilution water from the dredge slurry will separate from the dredge material within 24 hours, and can be directed offsite for treatment prior discharge back to Lake or to an off-site location for alternative use.

Information on volume of muds to be removed and equipment requirements for different time intervals is summarized in Table 9-1.

9.4.2.1 Full-scale Dredge Requirements

Increasing the production rate of the pilot dredge unit can be accomplished by increasing the width of the SEDCUT® sliding dredge head and adding more hydraulic pumps. The full-scale dredge unit needed to pump 4,270 gpm [16,000 l/min] of dredge slurry would be four times larger than the pilot unit (24 ft [7.3 m] wide with four, 6 in [15 cm] pumps equally spaced along the SEDCUT® dredge head). The variation of pump sizes and configurations can easily be tailored to maximize efficiency for scalability purposes; assuming a fairly fixed sediment layer thickness, the pilot dredge unit can be linearly expanded to the desired capacity merely by adding width and pumping capacity.

A major element of the cost of such dredging operations will involve the transport of the dredged material to the shore (or island) treatment and disposal site. For this aspect of the operation, there are many standard dredging techniques offering large economies of scale and reduced susceptibility to wind and water surface conditions. A series of fixed pipelines—each serving different segments of the Lake over the several years of the dredging operation—could offer much simpler and lower-cost transport and transfer operations, and much less weather and water-depth vulnerability than were encountered in this pilot study.

In addition, the observed fact that the mud layer is thickest at the center of the Lake and of negligible thickness as much as two miles from the shore on the perimeter, not only significantly reduces the area required for dredging, but also suggests even more interesting possibilities. For instance, it may be possible to only dredge the central (as an example) 10-mile diameter of the Lake, and exploit the natural forces that concentrate the mud in the center of the Lake over time to efficiently remove the majority of this material in a multi-year program.

Table 9-1 Full Scale Operation to dredge 200 Million yd^3 from Lake Okeechobee

Volume of Mud to be Removed	**Units**	**Total**
Volume of mud to be removed in yd^3 /yr	yd^3/yr	6,666,667
Volume of mud to be removed in gallons/yr	gal/yr	1,346,400,000
Volume of mud to be removed in yd^3/day	yd^3/day	18,265
Volume of mud to be removed in gal/day	gal/day	3,688,767
Volume of dilution water removed during dredging gals/day (35%)	gal/day	1,986,259
Total predicted volume of dredge slurry to be removed gals/day	gal/day	5,675,026
Total dredge slurry volume	GPM	3,941
Full Scale Dredge Edquipment Requirments		
Full scale unit (4 pumps 1,300 gpm/ea- 5,200 total)		
number of systems required based on 85% efficiency (4,420 gpm)		1
Dredged mud requiring storage		
Dredge slurry total flow rate	GPM	3,941
Dredge slurry total flow rate	yd^3/min	20
Volume of Sediment (65%)	yd^3/min	13
Total Sediment storage volume needed for 1 day	yd^3	18,265
Total Sediment storage volume needed for 1 day	acre-ft	11
Total Sediment storage volume needed for 1 year with 1ft thickness	acre-ft	4,132
Total Sediment Storage volume needed with 10 ft thickness	acre-ft	12,396
Dilution Water Volumes requiring treatment		
Dredge slurry total flow rate	GPM	3,941
Volume of dilution watger (35%)	GPM	1,379
Total water treatment requirements per day		2 MGD

9.4.2.2 Water Treatment Requirements

Both of the chemical treatment technologies implemented during the pilot project ($FeCl_3$ (ferric chloride) with polymer and FeCl with silica stabilization) were successful and were able to demonstrate a reduction of P_t below 40 ppb. In addition, the chemical treatment with FeCl and polymer addition was able to show reductions of P_t to levels below 10 ppb.

Based on the above estimates, production rates of the dredge slurry would be 6.1 MGD [23 million liters/day]. The slurry would be comprised of 65% mud and 35% dilution water. For forecast purposes, it is assumed that the dilution water collected in the dredge slurry will be directed to a separate water treatment plant (WTP) for potable water use or to the Aquifer Storage and Recovery (ASR) wells for subsequent potable water supply, or returned directly to the Lake. In any event, the dilution water volume, approximately 2.5 MGD [9.5 million liters/day], can be removed from the dredge material upland storage area within 24 hours, thus reducing the storage needs of the CDF(s).

Concentrations of the dredge slurry dilution water Pt levels after 24 hours of natural settling ranged during the pilot test from 140-260 ppb, and discharge of this water without treatment would require further research. While both of the chemical water treatment processes tested were successful in reducing Pt concentration to below 40 ppb, full-scale operations must include beneficial reuse of this water.

9.4.3 Conceptual Cost Estimate for Full-Scale Dredging Operations:

A rough order of magnitude cost estimate for the removal of 200 Million yd^3 [153 million m^3] is provide in Table 9.2. Since the development of a preliminary conceptual cost estimate without a developed conceptual plan is premature from a good engineering practice perspective, the costs are based on the production rates observed during the pilot test and the historical data produced by the USACOE for conventional hydraulic dredging. Dredging prices are assumed to be comparable to the conventional hydraulic dredge prices produced by the USACOE, since the SEDCUT® dredge head can be attached to conventional dredging equipment. However, higher production rates and better than average dredging prices are anticipated with further optimization of the SEDCUT® unit.

For these purposes, the projected full scale SEDCUT® unit is anticipated to be four times larger than the pilot unit used for this project. The full scale unit is assumed to operate 24 hours/day with an 85% operating efficiency. Based on these operating conditions, 200 million yd^3 [153 million m^3] could be removed in 30 years at a rate of 6.7 M yd^3 [5.1 million m^3] per year. Thus, two full scale units could complete the same volume in 15 years at similar unit rates.

Table 9.2 Cost Estimate for Full scale Operations

Task	Units	Cost	Cost/yr	30 yr Total
Dredging	6,666,667 yd^3	$3.02/$yd^3$	20.1 M	604 M
Land Disposal	3,333,333 yd^3	$1.73/$yd^3$	5.7 M	173 M
Water Treatment	730 MGY	$1,695/MG	1.2 M	36 M
TOTAL		**27M**	**813 M**	

Notes:

1. **Dredging costs** – Based on analysis of United States Corps of Engineers historical data (FY 01 Actual volume of 255,000 cy [195,000 m^3] @ $3.02/cy).
2. **Water Treatment Costs** – Based on analysis of RS Means Site Work (2002, historical water treatment cost data and chemical supplier prices, 1,696/million gallons, MG)
3. **Land Disposal Costs** – Based on analysis of SFWMD project land value of $4,600/acre and a dewatered sediment volume of 100 M yd^3 [76.5 million m^3] (50% water volume).

9.4.4 Design Considerations for Water Treatment Process Scale-Up

As is often noted, it is difficult to correlate the results of a pilot treatment system with the potential performance of a similar full-scale treatment system. However, the process of gathering data and observing the behavior of the system does provide insight into future scale-up design considerations. Following are observations, considerations, and recommendations:

- Further testing, to assess the need for pH adjustment during chemical precipitation/flocculation to develop optimized chemical usage and to meet effluent discharge criteria, is recommended.
- Iron removal or reduction of the effluent should be investigated.
- Process vessels were cleaned at the end of each day, and an accumulation of floc particulates at the bottom of both T-7 and T-8 was observed. Providing hydraulic conditions that create

full mixing and flow-through of these vessels to prevent particulate buildup should be a consideration in the design of future pilot systems or full-scale systems.

- The formation and settling dynamics of the particulates generated by the chemical precipitation/flocculation technology should be further investigated prior to full-scale design, to determine an adequate means of particulate formation and removal.
- The tube settler unit did enhance settling of the particulates generated by the chemical precipitation/flocculation technology, but it was not entirely effective. Tube settler units in a full-scale system may be a viable, cost-effective option; however, more testing is recommended.
- Disposal options for particulates that are generated during processing should be investigated.
- It is recommended that future pilot studies be implemented for extended periods of time, to allow for field adjustments of equipment and chemical feed to optimize the performance of the system.

9.5 PROJECT GOALS ACHIEVED/PERFORMANCE EVALUATION

The primary objective of the pilot dredging project was to demonstrate effectiveness of an innovative sediment dredging technology in removing the phosphorus laden mud sediment layer from the bottom of Lake Okeechobee, and doing so with a minimal contribution to turbidity in the in-lake water column. The SEDCUT® technology was specially developed to achieve this goal and field testing was conducted in Lake Okeechobee to determine efficacy of the specially manufactured innovative dredge head.

Results indicated that SEDCUT® technology was very successful in achieving the goals of the project. As shown previously, using a 6 in [15 cm] mouth opening and travel rate of 40 fpm [12 m/min], the SEDCUT® dredge head successfully removed a dredge slurry containing 65% target mud and 35% dilution water, which translates into 93% removal efficiency when compared to the predicted (theoretical) production rate (Table 5-4 and Figure 5-2). Comparison of predicted versus actual production rates for the 6 in [15 cm] mouth opening versus the 8, 10, and 12 in [20, 25.4, and 30.5 cm] mouth openings showed that the unit performed most effectively at a 6 in mouth opening and travel rate of 40 fpm [12m/min].

Also, as indicated earlier, review of the turbidity data did not indicate any significant increase in water column suspended solid levels that could be directly attributed to the operation of the dredge head. The lake waters are characterized by naturally high turbidity levels and no turbidity plume was observed during the field demonstration.

In short, the SEDCUT® technology is uniquely suited for conducting dredging under conditions typical of the Lake Okeechobee sediment bed for the following proven reasons:

1. It successfully and efficiently removes the targeted mud layer with minimal resuspension of solids.
2. It is not plagued by the limitations faced by conventional dredging techniques in removing fluid mud sediments (see Section 9.5.1).
3. It minimizes the amount of dilution water that is produced during dredging thereby reducing treatment and handling costs.
4. It can be used in shallow waters.
5. It can be easily scaled up for use in the larger areas of the lake where the sediments are known to be concentrated.
6. It is very cost-effective since it is assembled using mostly off-the-shelf products.

9.5.1 Comparison of SEDCUTÒ with Conventional Dredging Techniques

Standard conventional dredging techniques, such as mechanical and hydraulic dredging, have several inherent limitations, which hamper their use for removal of fluid muds. The SEDCUT® technology effectively overcomes all of these limitations. Common problems encountered when using conventional techniques to remove fluid muds include the following:

1. Mechanical dredging using clams buckets, drag buckets, back hoes, etc.

A) <u>Clam buckets (fully closing environmental designs)</u>

- Not efficient at capturing fluid muds as they tend to flow out of the closing bucket.
- Relatively low production rates, especially with thin daylight cuts.
- Resuspension problems from downward pressure wave of the descending bucket, mechanical dislodgement of sediments as bucket loads, bucket leakage, washing of sediments from external surfaces as bucket is raised through the water column, etc.
- Need to transport dredged material by barge or have a separate hydraulic slurry hopper and associated pipeline system.

- Difficult to remove material following the density plane of a substrate.
- Bucket loading tends to "craters" the bottom, possibly resulting in over dredging.
- Tends to leave material at the bottom with cut because of several reasons including: material running out as bucket closes, run-in of surrounding material, difficulty in overlapping bucket footprint patterns.

B) Drag buckets (conventional)

- Difficult to control bucket loading pattern or depth of cut.
- Severe resuspension problems with mechanical dislodgement and water flow from bucket toe eroding capture material as well as some considerations listed for clam buckets.
- Relatively low productive rates attempting to remove daylight materials.
- Usually need to have additional equipment to transport material.
- Bucket loading "strip craters" the bottom with excessive over dredging.
- Difficult not to leave material at the bottom of cut because material tends to run out as bucket is pulled forward; run-in of surrounding material, impossibility to overlap bucket cuts, etc.
- Bucket tends to follow path of least resistance and trends to remove material in an arc of pattern of "ditch-cuts."

C) Back Hoes

- Cannot capture fluid muds, material runs out of advancing bucket.
- Need to have "roll of material" to advance bucket to capture material with bucket curl.
- Relatively low production rates with day light cuts.
- Resuspension problems are common.
- Generally need to have additional equipment to transport materials.
- Difficult to follow a substrate density plane.
- Tends to leave material behind – from bucket run out and run in from surrounding materials.

2. Hydraulic Dredging

A) <u>Cutter/Suction Dredges</u>

- Thin cuts (e.g. daylight cuts) allow excessive dilution water to enter the suction mouth, yielding a very low solids content dredging slurry – i.e. 2-3 % solids by volume.
- Relatively low production rates – because solids concentration by volume is very low.
- Cross contamination is a common problem – resulting in a large volume of dilution water requiring treatment.
- Hard to follow a substrate density plane – dredge ladder mechanically held at a specific depth.
- Tends to leave material behind; advancing suction train allows surrounding material to run into dredge cut.

B) <u>Plain suction drag heads</u>

- Bottom entrenched drag head tends to remove substrate materials (i.e. over dredge).
- Significant weight of drag arm and head does not allow unit to plane on a low bearing capacity substrate (i.e. over dredge).
- Drag head makes a series of swathe cuts when advanced by ship propulsion, making it difficult to effectively overlap cuts, leaving material behind.
- Dredge ships drag requirements precludes operations in shallow waters.
- Dredging not continuous, need to transport and offload material after each dredging period.

9.6 RECOMMENDATIONS

1. The design of the SEDCUT® technology is inherently scalable for large-scale commercial dredging, additional data is needed to confirm the true potential of this exciting new technology. The implications of projecting from a prototype pilot dredge unit demonstration to a full-scale unit that can potentially remove up to 200 million cubic yards [153 million m^3][1]—an order of magnitude greater than any volume every dredged—are far reaching and should be considered with caution. In addition, the pilot dredging project removed sediments from only one location in the lake. It is therefore recommended that the SEDCUT® technology be further tested in the field at various locations in the Lake.

2. A demonstration project that will remove various mud thickness at variable water depths from different locations in the Lake is recommended, to provide additional data to more accurately forecast the cost and time necessary for evaluating a full-scale dredging operation.

[1]The total amount of fluid muds estimated to be present in Lake Okeechobee, as mentioned in the District RFP C-11651.

10.0 REFERENCES

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APPENDIX A

Regulatory Permits

APPENDIX B

GEOTECHNICAL AND PHYSICAL DATA

APPENDIX C

Field dredging operation photos

APPENDIX D

Water quality analytical data

APPENDIX E

Bathymetric Survey data

APPENDIX F

As-built photos of the Pilot water treatmentsystem

APPENDIX G

MSDS for water treatment additives

EA Engineering, Science, and Technology Inc.
15500 New Barn Road, Suite 200
Miami Lakes, FL 33014
(305) 819-2212